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THE STRUCTURE, STRATIGRAPHY, TECTONOSTRATIGRAPHY, AND EVOLUTION OF THE SOUTHERNMOST PART OF THE APPALACHIAN OROGEN, GEORGIA AND ALABAMA

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An account of the origins, assembly, transport, and arrival of three stacks of thrust sheets that make up the southernmost part of the Appalachian orogen.

This open-file report has not been edited and does not meet the standards of the U.S. Geological Survey. This report was originally submitted as a Professional Paper manuscript and will be superceded at a later time. To lessen the cost, figures 4, 13, 15, 19, 22, 25, 27, 29, 31, 39, and 43 have been omitted from the open-file report. Photos are photocopies of the originals.

ABSTRACT

The southernmost part of the Appalachian orogen in Georgia and Alabama is composed of three stacks of folded thrust sheets. The crystalline part of the orogen (including rocks now covered by the Coastal Plain) is composed of two thrust stacks, the (lower) Georgiabama thrust stack and the (upper) Little River thrust stack. Together with the Rome-Kingston thrust stack in the Valley and Ridge province, these thrust stacks preserve sequences of rocks formed in a wide variety of environments that virtually spanned the ancient Iapetus Ocean. The lowest thrust sheet in the Georgiabama stack preserves sequences of rocks considered autochthogenetic to the North American craton, whereas higher thrust sheets in the stack preserve sequences considered allochthogenetic to the North American craton. Sequences preserved in the Little River thrust stack are considered allochthogenetic to the North American craton, and autochthogenetic to the "African" craton. All of the rocks in the Rome-Kingston thrust stack are autochthogenetic to the North American craton.

Assembly (stacking) of the Georgiabama thrust stack took place from the Iapetus Ocean toward the North American craton, and from top to bottom, with the first-moving uppermost thrust sheets being the farthest-travelled and the later-moving lowermost sheets the least traveled. In contrast, the Little River stack appears to have been assembled from bottom to top as its sheets were being thrust upon the already assembled and moving Georgiabama stack. Thrusting took place continuously from about Middle Ordovician through Carboniferous time, and we suggest that virtually all of the folding and deformation in the southernmost Appalachians was caused by the North American cratonward-moving thrust sheets and thrust stacks. We suggest that most of the metamorphism and plutonism in the southernmost Appalachians was the result of the moving thrust sheets and thrust stacks and the insulating blanketing effects, the overpressures, and depths of burial they caused. Thrust sheets with different deformational and metamorphic histories are juxtaposed within the thust stacks.

The Georgiabama thrust stack is composed of 11 major thrust sheets. The uppermost thrust sheets (Soapstone Ridge and Ropes Creek) are obducted sheets of Iapetos Ocean mantle and crust. These overlie remnants of an ophiolitic, eclogite-bearing (West Point) subduction melange, that in turn overlies remnants of its associated oceanic (Paulding) island arc in the Paulding thrust sheet. The Paulding sheet overlies remnants of another (Promised Land) island arc and its fore-arc basin deposits (Sandy Springs, Promised Land, Atlanta, and Wahoo Creek thrust sheets), with its associated (Clairmont) subduction melange. Quartzites in some of the Sandy Springs sheet rocks have detrital zircons with ages of a billion years or older, indicating that the Promised Land arc formed at the edge of a microcontinent. Structurally beneath the Clairmont melange is the Zebulon thrust sheet composed of ocean-floor deposits with large contributions from the Ocoee basins and from the Promised Land arc. The lowest sheet in the Georgiabama stack is the autochthogenetic Bill Arp sheet, composed of nonvolcanic, mostly clastic and poorly sorted metasedimentary rocks deposited in a series of stepped (Ocoee) basins formed when the Iapetus Ocean opened; the Ductown assemblage of volcanic rocks and mafic hypabyssal intrusive rocks in the lowermost part of the clastic sequence was intruded into and erupted from rifts probably at the basin edges - massive sulfide deposits are found locally associated with the assemblage.

The Little River thrust stack is composed of the (structurally lowest to highest) Macon melange, Little River allochthon, and Northern Florida platform sequence; all considered allochthogenetic to the North American craton and autochthogenetic to an "African" continent (or microcontinent). The Little River allochthon is composed of thick sequences of mildly metamorphosed and mildly deformed volcanic, volcaniclastic, volcanic-epiclastic, and lesser amounts of

plutonic rocks of latest Precambrian (Late Proterozoic) through Middle Cambrian age that formed in a continental-margin island arc; the igneous rocks are bimodal and calcalkaline. Atlantic faunal province trilobites in some of the Little River allochthon rocks indicate that the continental mass where the Little River arc formed was not near North America, but may have been a microcontinent off the African continent. The Little River arcs subduction melange, the Macon melange, is well-preserved structurally beneath the Little River allochthon. The Macon melange contains clasts of all sizes of Iapetus Ocean crust and upper mantle, and pelagic cherts and manganiferous schists. The matrix is an imbricate complex of intershingled massive (but broken), coarse-grained, quartzose, feldspathic, semischistose and schistose, generally amphibole-bearing, biotite metagraywackes, semischists with thin broken metagraywacke beds, semischistose pebbly mudstones, and thin tuffaceous metacherts interbedded with scaly schist composed of manganiferous mica, plagioclase, and amphiboles. Above the Little River allochthon in the subsurface of southernmost Georgia and northern Florida is the Northern Florida platform sequence, composed of fossiliferous unmetamorphosed clastic rocks of Ordovician through Devonian age that are interpreted as deposited at the edge of the African craton.

The earliest record in the southern Appalachians of the opening of the Iapetos Ocean is the thick pile of peralkaline volcanic and immature clastic rocks that make up the Mount Rogers and Grandfather Mountain Formations in North Carolina, Virginia, and Tennessee, and in thinner sequences associated with massive sulfide deposits in the basal part of the Ocoee clastic metasedimentary sequence around Ducktown, Tennessee. Although these rocks are not well dated, the metavolcanic rocks were probably erupted at least 700 m.y. ago, and possibly over 800 m.y. ago. Volcanogenic components are absent in thick sequences of upper Precambrian (Upper Proterozoic)-Cambrian clastic metasedimentary rocks in the southern Appalachians through Early Ordovician time. Thus it appears that from the time of eruption of volcanic rocks in the Mount Rogers and Grandfather Mountain Formations, probably more than 800 m.y. ago, through the Lower Ordovician, the eastern margin of the North American continent was too far from any volcanic source to receive volcanogenic material. Reasonable spreading rates suggest that the Iapetus Ocean was wider than 10,000 kilometers when subduction zones and volcanic island arcs were established.

Closing of the Iapetus Ocean must have begun with establishment of one or more subduction zones. The rocks in the Little River allochthon are products of the volcanism associated with one of these subduction zones. These rocks probably span from very latest Precambrian (latest Proterozoic) through Middle Cambrian, indicating that at least by 600 m.y. ago the arc and subduction zone were active. Lack of volcanogenic rocks younger than Middle Cambrian in the Little River allochthon suggests that subduction under the Little River arc had ceased by Late Cambrian time. We offer the speculation that the Little River arc overrode the mid-Iapetus ridge during the Late Cambrian, thereby stopping subduction under the arc, and having the net effect of speeding up movement of the arc toward the North American continent until oceanic crust and upper mantle could no longer be consumed fast enough, so it buckled, broke (forming the Soapstone Ridge thrust sheet), and was obducted upon Ropes Creek Metabasalt (ocean crust). Collision began with obduction of Soapstone Ridge oceanic crust and mantle onto Ropes Creek oceanic crust, and obduction of Ropes Creek Metabasalt onto the West Point melange and Paulding island arc rocks. This stopped subduction under the Paulding arc and terminated volcanism and plutonism in the arc. Continued assembly of thrust sheets involved rocks of the Promised Land arc where subduction, volcanism, and plutonism had ceased, probably when the Clairmont melange and the arc overode the spreading center between the arc and North America. Continued movement thrust the Clairmont melange

and the overlying stack upon ocean-floor deposits (Zebulon Formation), and these in turn upon the lowest autochthogenetic Bill Arp thrust sheet.

Movement of the Zebulon thrust sheet and overlying stack onto the Bill Arp sheet caused buckling up of the Cambrian-Ordovician carbonate shelf at the oceanward edge of the North American craton, resulting in unconformities at the top of the Upper Cambrian-Lower Ordovician Knox Group, and later above the Middle Ordovician Lenoir Limestone. With continued movement, the cratonward edge of the Bill Arp sheet was thrust up along with part of the carbonate shelf above it to cause a landmass that separated the Rockmart-Athens basin from what was left of the Iapetos Ocean. Continued movement pushed parts of the pelitic sequences (Rockmart Slate, Athens Shale) up the paleoslope onto the unconformity at the top of the carbonate shelf, folding and mildly metamorphosing the pelites in the process. Erosion of thrust-up carbonate shelf sequence and Bill Arp thrust sheet rocks supplied clastic material to that basin, and continued movement and erosion of the thrust-up Bill Arp sheet rocks caused deposition and cratonward transgression (the source was also moving toward the craton) of a molasse-like, feldspathic, diamictite-bearing clastic wedge (Tellico-Talladega clastic wedge) that spread cratonward beyond the limit of the dark pelites, and farther cratonward another clastic wedge (Greensport, Colvin Mountain, Sequatchee). Further cratonward movement of the Clairmont melange and higher thrust sheets in the Georgiabama thrust stack probably loaded the underlying Zebulon and Bill Arp sheets and thereby the oceanward edge of what was left of the carbonate shelf allowing deposition of the thin Lower-Middle Devonian Armuchee Chert/Frog Mountain Sandstone (including Jemison Chert/Butting Ram Sandstone) sequence. By the late Middle Devonian or Late Devonian the Paulding, West Point melange, and Ropes Creek thrust sheets had locally transgressed far enough towards the craton to be emplaced upon the Lower-Middle Devonian craton-related Jemison Chert/Butting Ram Sandstone (Armuchee Chert/Frog Mountain Sandstone) sequence. While cratonward movement of the Georgiabama thrust stack continued, collision shoved the remnants of the Macon subduction melange wedge, the Little River island arc, preserved in the Little River allochthon, and African sedimentary deposits, preserved as the Northern Florida platform sequence, now beneath the Coastal Plain in southern Georgia and northern Florida, onto the top of the Georgiabama thrust stack, probably in late Carboniferous or Permian time. Final cratonward movement of the whole assembled set of thrust stacks took place along the Emerson, Talladega, Carters Dam, Rome-Helana, Clinchport, and Kingston faults during the late Carboniferous and Permian. The (lowest to highest) Kingston, Clinchport, and Rome thrust sheets, in the Valley and Ridge province, make up the Rome-Kingston thrust stack.

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INTRODUCTION

The concept of plate tectonics has breathed new life into the science of geology and revolutionized it in the same way that Einstein's theory of relativity revolutionized physics. This concept caused rapid advancement in understanding the northern Appalachians where geologists applied it to a wide inventory of careful field observations to produce a fascinating account of allochthons, ophiolites, melanges, and the opening and closing of the ancient Iapetus Ocean (Dewey, 1969; Bird and Dewey, 1970; Stevens, 1970; Dewey and Bird, 1971; Williams and others, 1972; Williams and Smyth, 1973; Williams and Talkington, 1977; Laurent, 1977; Rowley and Kidd, 1981). A similar story based on careful field observations soon began to emerge in the central Appalachians (Crowley, 1976; Morgan, 1977; Drake and Lyttle, 1981; Drake and Morgan, 1981; Pavlides, 1981; Lash and Drake, 1984). Observations and interpretations in the southern Appalachians lagged far behind.

We present data in this paper that show that the crystalline terrane of the southern Appalachian orogen in Georgia and Alabama (including rocks now covered by the Coastal Plain) is composed of two enormous stacks of folded thrust sheets (figs. 1-3). We (Higgins and others, 1984) refer to the lower thrust stack as the Georgiabama thrust stack, and the upper stack as the Little River thrust stack. Together with the Rome-Kingston thrust stack in the Valley and Ridge province, these thrust stacks preserve sequences of rocks formed in a wide variety of environments that virtually spanned the ancient Iapetus Ocean. The lowest thrust sheet in the Georgiabama stack preserves sequences of rocks considered autochthogenetic* to the North American craton, whereas higher thrust sheets in the stack preserve sequences considered allochthogenetic* to the North American craton (fig. 4). Sequences preserved in the Little River thrust stack are considered allochthogenetic to the North American craton, and autochthogenetic to the "African" craton. All of the rocks in the Rome-Kingston thrust stack are autochthogenetic to the North American craton (fig. 4).

Assembly (stacking) of the Georgiabama thrust stack took place from the Iapetus Ocean toward the North American craton, and from top to bottom, with the first-moving uppermost thrust sheets being the farthest-travelled and the later-moving lowermost sheets being the least travelled. In contrast, the Little River stack appears to have been assembled from bottom to top as its sheets were being thrust upon the already assembled and moving Georgiabama stack. Thrusting took place continuously from about Middle Ordovician through Carboniferous time, and we suggest that virtually all of the folding and deformation in the southernmost Appalachians was caused by the North American cratonward-moving thrust sheets and thrust stacks. By the same token, we suggest that most of the metamorphism in the southernmost Appalachians was the result of the moving thrust sheets and thrust stacks, the overpressures, depths of burial, and the blanketing effects they caused. Thrust sheets with different deformational and metamorphic histories are juxtaposed within the thrust stacks.

Deformation and metamorphism in the northern part of the Appalachian Mountain system have traditionally been ascribed to distinct orogenies, each marked in part of the system by fairly well-dated features (see Rodgers, 1982 for a recent review). Attempts to tie events in the southern part of the Mountain system (south of Roanoke, Virginia) to the same orogenies have mostly been unsuccessful, and the importance of "Taconic," "Acadian," and "Alleghanian" events has been the subject of much debate. Part of the problem arises from the fact that fossils have been

* We use the term autochthogenetic for allochthonous rocks derived from or otherwise genetically associated with a given craton, and the term allochthogenetic for allochthonous rocks that were apparently not genetically related to a given craton.

found only in very few localities in the crystalline part of the southern Appalachians, and apart from the inherent complexities involved in interpretation of radiometric age dates from multiply deformed, multiply metamorphosed rocks whose origins are not always well-understood. However, most of the problems in dating the metamorphism and deformation in the southern Appalachians have arisen from dependence on the "belt concept" that is so firmly entrenched here and from lack of recognition that the rocks here are in many different thrust sheets. Thus, well-dated rocks in one thrust sheet and well-dated rocks of a different age and with a different history in another thrust sheet have commonly been lumped together in the same "belt," thereby producing a confusing picture and the "geologic 1 noise" alluded to by Rodgers (1982, p. 235, 237).

We suggest that the metamorphism and deformation in the southernmost Appalachians was virtually a continuous process beginning with obduction of oceanic crust and mantle in the Soapstone Ridge thrust sheet onto Ropes Creek seafloor basalts, probably in the Ordovician, and lasting until plate collision and closing of the Iapetus Ocean was completed, probably during the Late Carboniferous or Permian. We consider the metamorphism and deformation, and also the plutonism, to be direct results of the thrusting and collisional processes and the depths of burial they caused. Thus, unconformities, periods of igneous intrusion, clastic wedges, metamorphism, and other features generally considered to mark distinct "orogenic events" are probably like rarely preserved frames of a long motion picture rather than vestiges of a spectacular series of still-shots. We suggest that the closing phase of the Iapetus Ocean should be called the Iapetan orogeny.

The stacking orders of the thrust sheets in the Georgiabama and Little River thrust stacks are based on considerable geologic field evidence, and the thrust fault at the base of each thrust sheet locally truncates mappable units in both the upper and lower plates; this is true of all but the smallest slices of thrust sheets. Without even considering the possible existence of a master decollement (Cook and others, 1979; Harris and Bayer, 1979; Cook and others, 1981), we consider all of the pre-Permian rocks southeast of the Kingston thrust fault in Georgia and the Helena thrust fault in Alabama (Chowns and McKinney, 1980; Chowns and Carter, 1983) allochthonous. Most of the thrust sheets in the Georgiabama thrust stack are found throughout the terrane between the Valley and Ridge province and the Little River thrust stack, so there is no real basis or reason for dividing a Blue Ridge geologic province (or belt) from a Piedmont geologic province in the southernmost Appalachians (fig. 1). Proposed times of thrusting and derivation of the thrust sheets are interpretive and are based on available geologic and geochronologic data. The facies reconstructions and the proposed developmental model presented in this paper are based largely on present understanding of plate tectonics. In addition, many of the units described here are tectono-stratigraphic units and do not conform to classic principles of superposition and stratigraphic succession (see Drake and Morgan, 1981).

We develop the following main themes in this paper: (1) That there was a continuity of geologic "events" in the development of the southernmost Appalachians that began with the inception of rifting of the ancient margin of North America to form the Iapetus Ocean and lasted until that ocean had closed and a new cycle of rifting began that resulted in the opening of the Atlantic Ocean; (2) That opening of the Iapetus Ocean was a slow process that probably took more than a hundred million years, and that as it opened it left a series of stepped fault-bounded basins (Ocoee basins) along the oceanward edge of North America, with long axes approximately parallel to the spreading axis. The basins nearest the spreading axis probably formed first and were filled with sediment first. The basins were filled first with poorly-sorted turbidic flysch deposits probably in enormous coalescing fans. Deposits in the basins had in general a common source and similar

depositional environments, but environments were probably diachronous from basin to basin and between basins. These deposits record the same type depositional environments throughout, even though the preserved "units" may not be directly "correlative" in age or continuity. When the basins had nearly filled (cratonward ones probably being the latest-formed and latest-filled) beach deposits and then carbonate shelf sequences with reefs formed on top of the clastic sediments. Part of the most continentward of these sequences is preserved as the carbonate shelf sequence in the Valley and Ridge province. Small parts of others are scattered around the crystalline terrane in such units as the Murphy, "Brevard," and Chewacla Marbles. These carbonate units probably mark the same depositional environment, but were probably deposited in separate basins and are probably slightly different in age; (3) At the same time as the last sediments in the cratonwardmost basins were deposited and the lower parts of the carbonate shelf sequence in the Valley and Ridge formed (latest Precambrian or earliest Cambrian) the Ocean had begun to close, subduction zones (with melange wedges) and volcanic arcs were established at the edge of the "African" continent, at the edge of a "Sandy Springs" microcontinent, and within the crust of the ocean; (4) The "African" plate overrode the mid-Iapetus ridge, probably in the Late Cambrian, stopping volcanism in the Little River island arc at the oceanward edge of the "African" continent and having the net effect of speeding up North American continentward movement of the plate. Oceanic crust and mantle buckled, broke, probably in the Late Cambrian or earliest Early Ordovician, and was obducted onto oceanic crust, thus beginning a thrust-stacking process that lasted until it involved the lowermost Bill Arp thrust sheet comprised of rocks of the opening-phase basins and their basement. As upper sheets moved onto lower sheets and these successively in turn onto still lower sheets they changed the environments they moved into and also those perhaps as much as hundreds of kilometers in front of the advancing sheets, including by Middle Ordovician time the cratonwardmost Valley and Ridge basin. Upthrust leading edges of the lower thrust sheet included sedimentary deposits belonging with those still forming in the basin, and these were cannibalized along with crystalline rocks in the sheet to form molasse wedges that spread onto the carbonate shelf. Folding took place continuously in front of the advancing thrust sheets with growing antiforms shedding debris into more cratonward basins. Thus, faulting, folding, and sedimentation were intimately interrelated. With continued cratonward advance uppermost sheets in the stack overrode middle sheets in the stack and transgressed far enough to be emplaced upon shallow-water Lower and Middle Devonian chert of the cratonwardmost (Valley and Ridge) basin; (5) Metamorphism was continuous and was caused by the depths of burial effected by the thick stacks of moving thust sheets, and by the blanketing insulation of the sheets, and this also caused anatectic melting of lower parts of the stack to produce plutonism; (6) The continuous orogenic process migrated along the edge of the North American continent from present northeast to present southwest because the Iapetus Ocean closed like a door hinged at the northeast. Thus, rocks formed in a given environment tend to be regionally diachronous along strike in the orogen; (7) Collision of the "African" plate caused emplacement of the Little River thrust stack comprised of the Macon subduction melange and Little River island arc of the "African" plate, and northern Florida platform sequence of the African continent upon the Georgiabama thrust stack. Final collisional stages caused emplacement of the entire assemblage of thrust sheets and stacks farther upon the rocks of the Valley and Ridge basin along the Emerson and Carters Dam faults as the African plate "docked," not with North America, but with the accreted terranes from the Iapetus Ocean.

The descriptions, interpretations, and conclusions presented in this paper are based on our detailed geologic mapping of the Atlanta, Georgia, and Griffin, Georgia 1° x 30' (1:100,000-scale) quadrangles (summarized in fig. 3), and most of

the Athens, Georgia, Milledgeville, Georgia, and Thomaston, Georgia 1° x 30' quadrangles, and extensive reconnaissance work throughout the crystalline terrane of Georgia and Alabama, with detailed work in problem areas; our work in the Carolinas has been mostly reconnaissance mapping. Figure 1 is modified from Alabama Geological Survey (1926, 1973), Crawford and Medlin (1973, 1974), Medlin and Crawford (1973), Cressler (1963, 1964a, 1964b), Crawford (1968a-f), Bentley and Neathery (1970), Georgia Geological Survey (1976), Chowns and McKinney (1980), Sears, Cook, and Brown (1981), Tull (1982), and Chowns and Carter (1983). We have benefited greatly from earlier work by Hurst (1955, 1973), Grant (1958), Hurst and Crawford (1964), Crawford and others (1966), Bentley and Neathery (1970), Medlin and Crawford (1973), Crawford and Medlin (1973, 1974), Cressler (1970, 1974), Neathery (1975), Dallmeyer and others (1978), Cressler and Crawford (in Cressler and others, 1979), Chowns and McKinney (1980), Horton (1981a), Tull (1982), Chowns and Carter (1983), and the unpublished mapping of Willard H. Grant. Stratigraphic nomenclature used in this paper is documented in Appendix A. Melange terminology used in this paper is after Drake and Morgan (1981), Hamilton (1979), Drake (oral commun., 1983, 1984), Moore and others (1985), and Cowan (1985). Precambrian is used preferentially over Proterozoic as a general time term in this paper (see Appendix A). We use ophiolite for any form of oceanic crust or mantle or any combination of the two. For time scales we use those of Harland and others (1982), Palmer (1983), and Salvador (1985), realizing discrepancies between them, and suggesting that they mark real margins of error in our knowledge of radiometric time versus paleontologic-stratigraphic (geochronometric versus chronostratigraphic) time (see Salvador, 1985, p. 181, 187). In Newfoundland, slice has been used in much the same manner as we use thrust sheet (for example: Williams, 1975). We use slice for separate pieces of a thrust sheet ("this slice of the Ropes Creek thrust sheet"), but also for pieces so large that they might be called separate sheets, but so related that we interpret them as sliced-off parts of the same sheet.

Previous concepts

For many years the crystalline rocks of the southernmost part of the Appalachian orogen in Georgia and Alabama were divided into poorly defined, locally named belts (Adams, 1933; Crickmay, 1952), generally assigned to two main geologic provinces (or belts), the Blue Ridge and Piedmont (King, 1955). More recently, belts defined mostly on the basis of reconnaissance in North Carolina (King, 1955) have been subdivided into still more belts (named mostly from the Carolinas), and projected and extrapolated through Georgia and Alabama by Griffin (1971) and Hatcher (1972, 1978), with little new geologic mapping.

Despite the findings of those who had mapped large areas in the southernmost Appalachians (for example: Bentley and Neathery, 1970; Crawford and Medlin, 1973; Medlin and Crawford, 1973; Hurst, 1973), the belt concept has become a "ruling concept" and has been used and accepted as the basis (and limitations) for developmental models for the southern Appalachians (Hatcher, 1972, 1978a; Hatcher and Odom, 1980; Price and Hatcher, 1983), for comparing the southern Appalachians with the better-known northern and Canadian Appalachians (Hatcher, 1981; Williams and Hatcher, 1982, 1983), and with part of the Canadian Cordillera (Price and Hatcher, 1983), for compilation of the southern part of a major tectonic lithofacies map of the Appalachian orogen (Williams, 1978), for interpretations of geophysical maps of the southern Appalachians (Hatcher and Zietz, 1978, 1980), for interpretations of deep seismic reflection profiles in the southern Appalachians (Cook and others, 1979; Cook and others, 1981; Cook and Oliver, 1981; Iverson and Smithson, 1982, 1983; Cook, 1983; Thomas, 1983; Ando and others, 1983), and for a proposal that "southern Appalachian thrusting" is a "model for orogeny" (Hatcher and Odom, 1980; Hatcher, 1981).

Williams and Hatcher (1982, 1983) have recently modified the belt concept in the southern Appalachians to one of accreted "suspect terranes," based largely on an earlier paper by Zen (1981). In these papers the belts are reduced in number (lumped) and referred to as "terranes," but they are still depicted as northeast-trending, discrete linear belts that are merely modifications of the southern Appalachian belts of Hatcher (1972, 1978a, 1981), Hatcher and Butler (1979), and Hatcher and Odom (1980).

In part due to the influence of the belt concept, the influence of Alpine structural concepts, and the lingering influence of the geosynclinal theory and the tectogene hypothesis, most of the crystalline terrane of the southern Appalachians has generally been depicted as composed of large fold-nappes that more or less match the belts (for example: Hatcher, 1972, fig. 3, 1981; Price and Hatcher, 1983, p. 155). The concept that the terrane between the Brevard Zone and the Towaliga fault zone in Georgia and Alabama is a single "Inner Piedmont allochthon" or "meganappe" (Clarke, 1952; Bentley and Neathery, 1970) has been accepted and expanded (Rankin, 1975, 1976; Hatcher, 1978a, 1981; Hatcher and Zietz, 1978, 1980; Sears, Cook, and Brown, 1981; Sears and others, 1981; Williams and Hatcher, 1982, 1983; Sears and Cook, 1984; Sears, 1985). The concept of belt-bound nappes has led to vigorous searches for root zones, generally thought to be subvertical and located at belt boundaries or within narrow belts such as the Brevard Zone ("Chauga belt" of Hatcher, 1972, 1978a), and particularly the "Kings Mountain belt," and more recently there has been a similar search in the same places for subvertical sutures (see Cook, 1983, and Rodgers, 1982 for discussions). The belts and the suspect terranes are considered to have "docked" with the North American craton and with each other as vertical entities, much as large ships dock against piers. With the exception of the "Goat Rock fault" which has been considered to bound one side of a window through to Grenville basement, thrust faults in the southern Appalachians have generally been depicted as long continuous unfolded unrepeated southeast-dipping features with the upper plate always on the southeast side (Hatcher, 1972, 1978, 1981; Tull, 1978, 1984; Hatcher and Odom, 1980; McConnell and Costello, 1980, 1984; Odom and Hatcher, 1980; Price and Hatcher, 1983; Glover and others, 1983, especially p. 226). Some of these faults are alternately depicted as pre-metamorphic and post-metamorphic (Hatcher, 1978, 1981; McConnell and Costello, 1980, 1984; Hatcher and Odom, 1980; McConnell and Abrams, 1984; Absher and McSween, 1985, p. 592), and Hatcher (1983, p. 260) describes faults as "pre- to syn- or late to postmetamorphic.."

Despite the fact that actualistic models show the invalidity of the miogeosyncline-eugeosyncline (geosynclinal) concept and the tectogene hypothesis (Hamilton, 1979), the Valley and Ridge province, and part of the crystalline terrane of the southern Appalachians as well, are still referred to by some authors as the "Miogeocline" (Williams and Hatcher, 1983 for example). The prevailing concept of metamorphism and deformation in the southern Appalachians is still one of a tectogene where "down-pulled," deeply buried rocks were metamorphosed and folded <u>after</u> they had "docked," thus producing broad "belts" affected by one distinct event or another.

In our opinion, the belt concept and the geosynclinal theory have greatly hindered understanding of the geology and geologic history of the southern part of the Appalachian orogen and have caused misrepresentation of the geology of the southern Appalachians to the scientific community. Neither the "belts" nor the "suspect terranes" are (Williams and Hatcher, 1983, p. 34) "internally homogeneous geologic provinces, with features that contrast sharply with those of nearby provinces". There is no "miogeocline" because there was neither a "eugeosyncline" nor, for that matter, a "geosyncline," and virtually all attempts to correlate units in the Valley and Ridge province with those in the crystalline terrane have

not proved valid. The basic structure of the crystalline terrane in the southernmost Appalachians is not one of steeply bounded belts "docked" against one another and the craton like dominoes, but of now-folded, but once nearly horizontal, thrust sheets.

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THE GEORGIABAMA THRUST STACK

The Georgiabama thrust stack is composed of 11 major thrust sheets in Georgia and Alabama (fig. 2); additional sheets are probably present to the northeast. Lower sheets in the stack are widely preserved and underlie vast areas of the crystalline terrane. Higher sheets are less widely preserved and the uppermost sheets occur as scattered remnants (for example, the Soapstone Ridge sheet - figs. 1 and 3), either because of erosion, or because they broke up during transport and emplacement, or more likely, both. The lowest, Bill Arp sheet is considered autochthogenetic, and all higher sheets allochthogenetic.

Bill Arp thrust sheet

The composite Bill Arp thrust sheet is the basal thrust sheet in the Georgiabama thrust stack (fig. 2). It crops out in areas that are essentially windows through the overlying thrust sheets (figs. 1 and 4). At the boundary between the crystalline terrane (Piedmont and [or] Blue Ridge of former usage) and the Valley and Ridge province the Bill Arp thrust sheet is bounded below by the Emerson* and Talladega thrust faults (Crawford and Cressler, 1982; Tull, 1982), or by the Carters Dam fault**, but through most of the crystalline terrane of Georgia and Alabama the Bill Arp sheet may be bounded below by a master decollement (Cook and others, 1979; Harris and Bayer, 1979; Cook and others, 1981) or (and) splays off a master decollement. The Bill Arp sheet is composed of rocks belonging to the Grenville basement, upon which were deposited rocks belonging to the upper Precambrian Ocoee Supergroup, rocks belonging to or correlative with the upper Precambrian or Lower Cambrian(?) Ellijay Group, rocks belonging to or correlative with the lower Paleozoic Blue Ridge Group, and rocks belonging to the uppermost Precambrian and Lower Cambrian Chilhowee Group (fig. 4, table 3a). The most characteristic feature of the Bill Arp thrust sheet is its virtual lack (with a notable exception) of volcanic components of any kind (amphibolites, volcaniclastic

* Formerly the Cartersville fault.
** Formerly the Great Smoky fault.

rocks, volcanogenic sediments, etc.). This lack of volcanic components is characteristic of the entire Ocoee basin(s), as emphasized more than 25 years ago by King and others (1958), and more recently by Hurst (1973). As far as we know, except for granites, granite gneisses, and the Talladega Group (sensu-stricto - discussed in a later section), rocks of the Bill Arp thrust sheet form the only large outcrop areas in the Georgia and Alabama crystalline terrane that are without volcanic components (metavolcanic rocks in the Bill Arp sheet around and southwest of Copperhill, Tennessee, are discussed in a later section).

Another characteristic of the Bill Arp thrust sheet is the presence of small, regionally discontinuous metamorphosed carbonate rocks generally within the upper parts of its thick metasedimentary sequences. As Hurst (1973) recognized, metacarbonate rocks are relatively rare in the crystalline terrane of Georgia and Alabama, being apparently limited to the small metacarbonates in the Ocoee metasedimentary sequences (including Brevard Zone metacarbonates - see below), and the Murphy and Chewacla Marbles.

Still another characteristic of the Bill Arp sheet is that many of its rocks are rich in titanium, barium (Appendix B), and carbon; the carbon is typically in the form of graphite and the titanium in the form of rutile or ilmenite. This is true of most of the Grenville basement rocks as well as the Ocoee metasedimentary rocks above the basement.

In Georgia, named stratigraphic units thus far recognized as part of the Bill Arp thrust sheet are: the Grenville-age Corbin Gneiss of the Allatoona Complex (Appendix A), Wiley Gneiss of Hatcher (1974), Woodland Gneiss, Cunningham Granite and Sparks Schist of the Wacoochee Complex (Appendix A); the Copperhill, Ola, Richard Russell, Wehutty, Frolona, Kalves Creek, Hughes Gap, Bill Arp, Hothouse, and Dean Formations of the Great Smoky Group (Appendix A; table 1); the Hollis Quartzite, Manchester Schist, Mountain Creek Formation, and Chewacla Marble of the Pine Mountain Group (Appendix A; table 1); the Nantahala Formation, Tusquitee Quartzite, Brasstown Formation, and Murphy Marble of the Ellijay Group (Appendix A), the Andrews Formation, Nottely Quartzite, and Mineral Bluff Formation of the Blue Ridge Group (Appendix A); and the Cochran, Nichols, Wilson Ridge, and Weisner Formations (Mack, 1980) of the Chilhowee Group (Hewett and Crickmay, 1937; Crickmay, 1952; Hurst, 1955; Herndon, 1965, 1968; Crawford and Medlin, 1974; Dallmeyer and others, 1978; Mack, 1980)*. In Alabama, rocks of the Bill Arp thrust sheet (many are the same units found in Georgia) have been given various names, including parts of the Wedowee, Hatchet Creek, Mad Indian, Heard, Jacksons Gap, and Opelika Groups, and the Moffits Mill Complex (Bentley and Neathery, 1970; Neathery, 1975). We have not yet separated the Bill Arp thrust sheet from the overlying Zebulon thrust sheet in much of the Alabama crystalline terrane, where in most areas rocks belonging to both sheets have been mapped together as formations or groups (Bentley and Neathery, 1970; Neathery, 1975; Alabama Geological Survey, 1973). The bulk of the rocks above the Grenville-age basement in the Bill Arp thrust sheet are probably late Precambrian, and part of the Ocoee Supergroup (King and others, 1958).

In the area of figure 3, the Great Smoky Group (undivided) and Bill Arp Formation constitute parts of a turbidite flysch assemblage that was probably part of a submarine fan. The Great Smoky consists of fine-grained metasiltstones in sedimentation units as much as 3 meters thick interbedded with fine-grained schist and phyllite sedimentation units about 3 to 30 meters thick. Interspersed with the finer grained rocks are fine- to medium-grained metagraywacke conglomerates containing blue quartz granules, as well as very graphitic schists and phyllites that

* The Cochran, Nichols, Wilson Ridge, and Weisner Formations of the Chilhowee Group are adopted as defined by Mack (1980).

Table 1. Stratigraphic units and depositional correlations in the Great Smoky and Pine Mountain Groups of the Ocoee Supergroup in Georgia.

Murphy synclinorium	Richard Russell thrust slice	Austell-Frolona synclinorium	Ola synclinorium	Pine Mountain synclinorium
Great Smoky Group	Great Smoky group	Great Smoky group	Great Smoky Group	Pine Mountain Group
Dean Formation				
Nothouse Formation				
				Chewacla Marble
Hughes Gap Formation		Bill Arp Formation		Mountain Creek Formation
Wehutty Formation		Frolona Formation	Rolves Creek Formation	Manchester Schist
			unnamed quartzite	Hollis Quartzite
Copperhill Formation	Richard Russell Gneiss		Ola Formation	

locally can be mapped. This sequence is interpreted to be a proximal turbidite assemblage.

About 25 km to the southeast of the Great Smoky Group (undivided), in the Austell-Frolona anticlinorium (fig. 3), the correlative Bill Arp Formation can be roughly divided into two gradational sequences. The lower and older sequence consists of medium-grained, graded metagraywacke about 0.3 to 3 meters thick, rhythmically alternating with fine- to medium-grained schist units of about the same thickness. Graded bedding is virtually ubiquitous in this sequence and well-preserved, and clearly documents the anticlinal character of the major Austell-Frolona fold (figs. 5 and 6) and the stratigraphic (and tectonostratigraphic) position of the Bill Arp Formation. The metagraywacke beds have straight and even bases, and appear to lack high-energy features such as flute casts, sole marks, or flame structures. Within the Austell-Frolona anticlinorium the lower sequence grades gradually upwards into a younger sequence of more massive, less well-graded, thicker (1-4 m) metagraywacke beds that have thinner (generally less than 1 m) schist intervals. The metagraywacke beds in this sequence are commonly more calcareous than those in the lower sequence, and in several outcrops (on both limbs of the fold) they contain deformed calcareous concretions (Sanders and others, 1979) as much as a meter long (fig. 7). The entire sequence above the Frolona Formation in the Austell-Frolona anticlinorium probably represents slope turbidites grading upward into slightly less distal turbidites within a fan. If our interpretations are valid, then the combination of proximal facies on the northwest (Great Smoky Group undivided) with more distal turbidites to the southeast suggests that the Ocoee basin(s) in this part of Georgia was filled from the northwest, by the construction of enormous coalescing submarine fans. This is supported by geochemical data (Appendix B) linking some of the metasedimentary rocks in the Great Smoky sequence to the Grenville-age Corbin Gneiss basement (Odom and others, 1973; T.W. Stern, oral commun., 1984), east of Cartersville, Georgia, as a source.

In the Austell-Frolona anticlinorium, the Bill Arp Formation is underlain by the Frolona Formation (Crawford and Medlin, 1974; figs. 1 and 3; table 2). The Frolona consists mostly of muscovite schists that are generally graphitic and garnetiferous, and also generally contain staurolite or kyanite. Discontinuous micaceous quartzites, clean quartzites, and quartz-pebble metaconglomerate are also common in the Frolona. An important characteristic of the Frolona is the widespread occurrence in some of its schists and quartzites of small, well-formed crystals of rutile.

About 50 km southeast of the Austell-Frolona anticlinorium, the Bill Arp thrust sheet is again exposed in the Ola anticlinorium (fig. 3), where the sheet is composed of the Ola and Kalves Creek Formations. The Ola is a thick sequence of medium- to coarse-grained schists with lensoidal units of biotite-plagioclase gneiss (metagraywacke or metasiltstone). The overlying Kalves Creek Formation is composed of medium- to coarse-grained schists, minor amounts of biotite-plagioclase gneiss, and distinctive yellow- to white-weathering, spindly, graphite-sillimanite schist. The Kalves Creek is lithologically similar to the Frolona Formation, its probable depositional equivalent. The Ola is lithologically similar to the Copperhill Formation in the Murphy synclinorium in northern Georgia, and the Kalves Creek Formation is lithologically identical to the Wehutty Formation which overlies the Copperhill (see Dallmeyer and others, 1978). Schists in the Wehutty contain small, well-formed rutile crystals.

Still farther to the southeast, the Pine Mountain Group (Hewett and Crickmay 1937; Clarke, 1952; Bentley and Neathery, 1970; Sears and others, 1981; Appendix A) is a sequence of schists, biotite gneisses (metagraywackes), quartzites, and lesser amounts of marble, without volcanic components. The schists and gneisses are lithically identical with parts of the Great Smoky Group to the north. Nearly

white graphite-sillimanite schists of the Manchester Schist are lithic matches of the Wehutty and Kalves Creek Formations and part of the Frolona Formation, and these schists contain small amounts of rutile (also see Hewett and Crickmay, 1937, p. 29, and Bentley and Neathery, 1970, p. 36). These schists are overlain by the Mountain Creek Formation (named - Appendix A), a schist and graywacke unit that is identical with the Bill Arp and Hughes Gap Formations to the north (table 1). We suggest that all of these units represent the same depositional environments within the Ocoee basins.

Hewett and Crickmay (1937) and Bentley and Neathery (1970) considered the Pine Mountain Group to consist of only the Hollis Quartzite, Manchester Schist, and Chewacla Marble, and placed the Sparks Schist in the basement (Wacoochee Complex of Bentley and Neathery, 1970). We agree that the rocks that have been assigned to the Sparks Schist or Sparks Formation (Sears and others, 1981) belong to the Grenville basement. In support of this assignment are: (1) Structural relations between the rocks beneath the Hollis Quartzite (including Sparks Schist) suggest an unconformity. Near their contact with the Hollis these rocks have been deformed into parallelism with the Hollis, but away from that contact the structure in the basement rocks is discordant to that in the Hollis and overlying rocks as noted by Hewett and Crickmay (1937) and Clarke (1952); and (2) The rocks beneath the Hollis are extensively "granitized" and cut by thin granitic bodies, whereas these features are not found in the overlying rocks as recognized by Crickmay (1952, p. 23) and Bentley and Neathery (1970, p. 34). What has previously been mapped as Sparks Schist or Sparks Formation (Hewett and Crickmay, 1937; Clarke, 1952; Bentley and Neathery, 1970; Sears and others, 1981) consists of two different rock types: (1) sheared gneisses (including granulitic gneisses) that are now "schists," and (2) true metasedimentary pelitic schists. It can locally be shown that the sheared gneisses grade into massive granulite. The pelitic schists are "grungy" red, extensively granitized, coarse-grained rocks that occur as the country rock between the granulitic plutons, and also as xenoliths and roof pendants in the plutons; the name Sparks Schist should only be used for these pelitic schists (see Appendix A). Locally the Sparks Schist contains thin metagraywacke beds.

We consider the Pine Mountain Group to consist of (from lowest to highest) the Hollis Quartzite, Manchester Schist (as modified in this paper), Mountain Creek Formation (named in Appendix A), and Chewacla Marble. The name Manchester Schist is retained for the unit of graphitic sillimanite schist that overlies the Hollis. This schist is overlain (apparently gradationally) by the Mountain Creek Formation which consists of pelitic schists interbedded with metagraywackes. The Manchester is the depositional equivalent of the Wehutty and Kalves Creek Formations and part of the Frolona Formation, all belonging to the Great Smoky Group of the Ocoee Supergroup (table 1). The Mountain Creek Formation is the depositional equivalent of the Hughes Gap and Bill Arp Formations of the Great Smoky Group. We assign the Pine Mountain Group to the Ocoee Supergroup, but retain the separate group status of the Pine Mountain because of geographic separation from other Great Smoky rocks and because of its traditional use in the Pine Mountain block.

In Georgia the Pine Mountain area (fig. 8) contains granulitic rocks that have been considered "Grenville basement" (Odom and others, 1973; Rankin, 1975, 1976; Schamel and Bauer, 1980; Schamel and others, 1980; Sears and others, 1981; Sears, Cook, and Brown, 1981; Hatcher, 1983; Williams and Hatcher, 1982, 1983; Hatcher and others, 1983; Hatcher and others, 1984; Sears and Cook, 1984). Assignment of these rocks to "Grenville basement" was made because of the similarity of the structurally overlying Pine Mountain Group to late Precambrian Ocoee Supergroup sequences, or the Murphy Group sequence, or Chilhowee Group sequences in the Murphy synclinorium and the anticlinorium west of it, or lower Paleozoic sequences in the Valley and Ridge province, and because of Odom and others' (1973) report of a U-Pb zircon age

in excess of a billion years from Pine Mountain "basement" rocks. The reported zircon age must be considered with caution because it was reported only in an abstract (Odom and others, 1973), giving no analytical data other than the age, and there has been no subsequent publication of the data. Nevertheless, massive and poorly foliated charnokitic and other granulitic rocks are present structurally beneath the Pine Mountain Group (Great Smoky Group equivalents) in the Pine Mountain area in Georgia (also see Stieve, 1984; Sears and Cook, 1984) and are reasonably assigned to Grenville basement. This means that the Sparks Schist, which has been intruded, granitized, and metamorphosed by the Grenville granulitic plutons, is probably one of the oldest rocks in the crystalline terrane of the southernmost Appalachians. This basement complex composed of the Sparks Schist and various Grenville-age plutonic rocks was called the Wacoochee Complex by Bentley and Neathery (1970), and this Alabama name has precedence even though the rocks are better exposed in Georgia; we here assign all of the Grenville basement rocks in the Pine Mountain anticlinorium to the Wacoochee Complex (Appendix A).

There are problems with interpretations of the structure of the Pine Mountain area. Clarke (1952) first suggested that the Goat Rock, Towaliga, and Brevard "faults" are the same fault, thus interpreting the rocks south of the Goat Rock and between the Towaliga and the Brevard as part of the same enormous allochthon. This idea was expanded by Bentley and Neathery (1970), Rankin (1975), Schamel and Bauer (1980), Schamel and others (1980), Sears, Cook, and Brown (1981), Sears and others (1981), Sears and Cook (1984), and Sears (1985). The northern boundary of the Pine Mountain sequence, the Towaliga fault (or fault zone; see Grant, 1967, 1968), has most recently been considered to be a normal fault (Schamel and Bauer, 1980; Schamel and others, 1980; Sears, Cook, and Brown, 1981; Sears and others, 1981; Sears and Cook, 1984) which along with the Goat Rock fault (or fault zone) is interpreted to bound a structural and erosional "Pine Mountain window" through the "crystalline Piedmont allochthon" (Sears and Cook, 1984, p. 281) or the "Piedmont-Blue Ridge allochthon" (Sears, 1985) to Grenville basement. The rocks within the "window" (Pine Mountain Group and Grenville basement) are interpreted to reside in large refolded nappes (Schamel and Bauer, 1980; Sears, Cook, and Brown, 1981; Sears and others, 1981; Sears and Cook, 1984; Sears, 1985).

The nappe interpretation of the Pine Mountain block is dependent on (Sears and others, 1981, p. 45-46): (1) correlation of the "upper schist member" of the Manchester Formation of Clarke (1952) with the Sparks Schist of Hewett and Crickmay (1937); (2) correlation of the Sparks Schist in Georgia with the Halawaka Schist (of Bentley and others, 1982) in Alabama; (3) the Halawaka Schist, which Bentley and others (1982) included with Wacoochee belt ("basement") units in Alabama, belonging with the Pine Mountain Group; and (4) the "quartzite member" of the Manchester Formation of Clarke (1952) being "equivalent" to Hollis Quartzite. We agree with Sears and others (1981) that the "quartzite member" of the Manchester Formation is the Hollis Quartzite; it maps directly into Hollis Quartzite to the northeast (figs. 8 and 9) and is in the correct place in the stratigraphic section. However, the "upper schist member" of the Manchester Formation of Clarke (1952) is not equivalent to the Sparks Schist of Hewett and Crickmay (1937); the "upper schist member" is Manchester Schist of the Pine Mountain Group, whereas the Sparks is part of the Grenville basement. The Halawaka Schist of Bentley and others (1982) belongs with the Sparks Schist in the Wacoochee Complex of Grenville basement. The structure of the Pine Mountain anticlinorium is compatible with some of the Georgia cross sections in Sears and others (1981, p. 43, fig. 2 a, and less so b), but not with the Georgia section in Sears and Cook (1984, p. 283, fig. 2, b), nor with any of the sections presented by Sears (1985).

We do not consider the Pine Mountain block to be a window because: (1) What has been mapped as the Goat Rock fault locally coincides with the Macon melange

thrust fault at the base of the Little River thrust stack (figs. 2 and 34), does not represent a normal fault along which uplift of the Pine Mountain block took place, and certainly is not the same fault as the Towaliga or the Brevard; (2) Our work shows that there is no evidence for equivalency of the Brevard Zone and the Towaliga fault zone, and certainly no evidence that the rocks between the Brevard and the Towaliga reside in a single "Inner Piedmont meganappe," "Piedmont allochthon," or "Piedmont-Blue Ridge allochthon." In fact, there is an abundance of data to the contrary; and (3) We have found no rocks south of the Pine Mountain block (fig. 8) that are also present north of the block -- the southern border of the block is the Macon melange. Small slices of the Zebulon thrust sheet are found along the northern edge of the southern border of the block.

The northwestern boundary of the Pine Mountain block is a complex zone of mylonites, polymylonitic rocks, and brittle cataclastic rocks that has long been called the Towaliga fault or fault zone (Crickmay, 1933, 1939, 1952; Clarke, 1952; Grant, 1967, 1968; Bentley, 1969; Higgins, 1971; Schamel and Bauer, 1980; Schamel and others, 1980; Sears and others, 1981; Sears, Cook, and Brown, 1981). Our work indicates that there is a Towaliga normal fault with the northwest side downthrown relative to the southeast side, and also a complex Towaliga fault zone with a more complicated movement history.

The Towaliga fault zone is a discontinuous zone of mylonite, blastomylonite, button schist, and mylonite gneiss as much as two kilometers wide (fig. 1). The ductile mylonitic nature of these rocks suggests that they formed at high pressures and relatively high temperatures, and are thus considered older than the normal fault that has caused uplift of the Pine Mountain block relative to the rocks to the northwest. These rocks are poorly understood, but we suggest that they formed in deep-seated parts of an imbricate thrust zone that occurred in the lower thrust sheets and basement in the Georgiabama thrust stack. This thrust zone probably resulted from northwestward adjustment of the Grenville basement and Bill Arp thrust sheets as they were overidden by the Georgiabama thrust stack. Complex movement along the fault zone probably also involved a strike-slip component (Grant, 1967, 1968) in response to the stack arriving at an angle to the trends in the Bill Arp thrust sheet protoliths and the Grenville basement.

The normal fault along which the Pine Mountain block has been uplifted relative to the rocks to the northwest is generally marked by a relatively thin zone of brittle microbreccias with a fabric that generally dips to the northwest 40-60 degrees (also see Grant, 1967, 1968); some of these are microbreccias formed from the earlier mylonitic rocks. It cuts across the earlier ductile zone and the fabric of mylonitic rocks in that zone. The northwest dip of fabric in the microbreccias has generally been taken to indicate that the normal fault dips northwest (as it is shown in figures 9 and 61o), but this has not been proven. The Towaliga fault has also generally been considered to have great vertical displacement; this may not be true, either. In the stretch between Barnesville, Georgia, and Woodbury, Georgia (figs. 1 and 9) Pine Mountain Group (Great Smoky Group depositional correlatives - see Appendix A) rocks (Hollis Quartzite, Manchester Schist, and Mountain Creek Formation) in the Bill Arp thrust sheet on the southeast side of the fault zone are juxtaposed against rocks of the Zebulon Formation in the Zebulon thrust sheet on the northwest side of the zone (mylonitic rocks intervene in many places), suggesting relatively large vertical displacement. However, northeast of Barnesville and southeast of Pine Mountain, Pine Mountain Group rocks (not including the Hollis Quartzite) are found on both sides of the fault zone (locally the fault is intraformational), indicating that the displacement may not be as great as generally thought (nor as shown in fig. 61o).

Southeast of the Towaliga fault, and trending parallel with it, is the Shiloh fault (Schamel and Bauer, 1980; Sears and others, 1981), which is also a normal

fault with its southeast side upthrown relative to its northwest side (fig. 9). The age of the normal faulting is unknown, but the one-sided-hoarst nature of the geometry it has created is not incompatible with a suggestion that it occurred as the Little River thrust stack moved onto the Georgiabama thrust stack. Could the loading from the southeast (present direction) have seesawed the crust to initiate the present fault configuration?

Most of the Blue Ridge physiographic province in northern Georgia is underlain by rocks of the Ocoee Supergroup, rocks of the Ellijay and Blue Ridge Groups (former "Murphy Group"), rocks of the Chilhowee Group, and relatively rare Grenville-age basement rocks in the Bill Arp thrust sheet. These rocks have generally been considered to crop out in an enormous anticlinorium, which has been called the "Blue Ridge anticlinorium" (for example, Hatcher, 1972, fig. 4). However, the work of Hurst (1955), Fairley (1965), Herndon (1965, 1968), Power and Forrest (1971, 1973), Forrest (1975), Dallmeyer and others (1978), and our own work indicates that the major structure of the area is a huge synclinorium (Murphy synclinorium), even though most of the rocks in the synclinorium belong to the lowest thrust sheet in the Georgiabama thrust stack. Most of the area is underlain by rocks that are extremely resistant to erosion; some of these same rocks make the Pine Mountain block physiographically more like the physiographic Blue Ridge than the physiographic Piedmont (Hack, 1982). Grenville-age basement rocks are known only in structurally complex anticlinoria on the western flank of the Murphy synclinorium (Bayley, 1928; Fairley, 1965; Crawford and Cressler, in Cressler and others, 1979; McConnell and Costello, 1984); rocks that possibly belong to the Grenville basement (Wiley Gneiss - Hatcher, 1974) occur some distance east of the flanks of the Murphy synclinorium around the flanks of another complex structure that has been called the "Tallulah Falls dome" (Hatcher, 1973; 1976; 1983). Great Smoky Group rocks on the eastern flank of the Murphy synclinorium (fig. 1) have been overridden by rocks of the Zebulon, West Point melange, and Ropes Creek thrust sheets, and by the Richard Russell thrust slice (Bill Arp thrust sheet). Infolded remnants of the Zebulon, West Point, Ropes Creek, and Soapstone Ridge thrust sheets are scattered widely over the synclinorium (fig. 1).

Between the Carters Dam fault and the western flank of the Murphy synclinorium, known Grenville basement crops out in three main areas: (1) east and northeast of Cartersville; (2) in the Salem Church area near Jasper; and (3) around Fort Mountain near Chatsworth (fig. 1). We assign all of these basement rocks to the Allatoona Complex (Appendix A).

The axial area of the Murphy synclinorium (the part that has traditionally been called the Murphy syncline) is occupied by the Ellijay and Blue Ridge Groups (Appendix A) and the flanks by the Great Smoky Group. The Richard Russell Gneiss (Appendix A) in a separate thrust slice on the eastern flank of the Murphy synclinorium is a volcanic-free unit composed of sheared but massive biotite gneiss and lesser amounts of schist, which we assign to the Ocoee Supergroup. It is probably coeval with the lower units of the Great Smoky Group. The Great Smoky Group consists (in ascending order) of the Copperhill, Wehutty, Hughes Gap, Hothouse, and Dean Formations (table 1). The Murphy Group has generally been considered composed of (in ascending order) the Nantahala Formation, Tusquitee Quartzite, Brasstown Formation, Murphy Marble, Andrews Formation, Nottely Quartzite, and the Mineral Bluff Formation (table 2). Hurst (1955, p. 8) suggested the possibility of an unconformity beneath the Nantahala Formation, and assigned the Great Smoky Group in Georgia to the Precambrian and the Murphy Group to the Cambrian. Tull and Guthrie (1983) suggested that an unconformity equivalent to the "pre-Lay Dam Formation unconformity" of Tull (1982) beneath the Talladega Group in Alabama is present within the Murphy Group, either above or within the Andrews Formation. They suggested that the Murphy Marble is stratigraphically equivalent to the lowermost

Table 2. Stratigraphic units in the Ellijay and Blue Ridge Groups in Georgia.

Traditional	This Paper
Murphy Group*	Blue Ridge Group
Mineral Bluff Formation	Mineral Bluff Formation
Hottely Quartzite	Hottely Quartzite
Andrews Schist	Andrews Schist
	--unconformity--
	Ellijay Group
Murphy Marble	Murphy Marble
Brasstown Formation	Brasstown Formation
Tusquitee Quartzite	Tusquitee Quartzite
Hantahala Formation	Hantahala Formaiton
	--thrust fault--
Great Smoky Group	Great Smoky Group

* The Murphy Group of Hatcher (1972), Murphy Belt Group, and Murphy Marble Group are here abandoned (Appendix A).

part of the "Sylacauga Marble group" beneath the unconformity, and that the Nottely Quartzite and the Mineral Bluff Formation are equivalent to the lower part of the Talladega Group. They suggested that the upper part of the "Sylacauga Marble group" is absent above the Murphy Marble because of a deeper level of erosion below the unconformity, and interpreted the Kahatchee Mountain Group of Tull (1982) to be the stratigraphic equivalent of the Murphy Group below the Murphy Marble as well as "perhaps of the upper part of the Precambrian Great Smoky Group." More recently, Guthrie (1984) suggested, based on "lithostratigraphic relationships," that the Kahatchee Mountain Group in Alabama is equivalent to parts of the Walden Creek and Chilhowee Groups and the lower part of the Murphy Group in northern Georgia, that the lower part of the Murphy Group in northern Georgia may be a facies of the Chilhowee Group and Early Cambrian in age, and that "An upper age constraint for the KMG (Kahatchee Mountain Group) is provided by Early Ordovician conodont elements in the overlying Sylacauga Marble Group."

The "Sylacauga Marble group" is now known to be part of the Valley and Ridge (in the Rome thrust sheet) and probably mostly part of the Knox Group (Harris and others, 1984), just as Shaw (1970; 1973) mapped it more than a decade ago. Most interpretations of the stratigraphy and regional correlations of the "Murphy Group" have centered around correlation of the Murphy Marble with lower Paleozoic carbonate units in the Valley and Ridge province; the most common correlation has been with the Lower Cambrian Shady Dolomite in the Rome thrust sheet, and thus the lower units of the Murphy Group have been correlated with the Chilhowee Group. However, the Murphy is a relatively "clean" marble (Hurst, 1955; Fairley, 1965; Power and Forrest, 1973), and not the type of carbonate deposit that would be expected oceanward from the shelf environment of the lower Paleozoic carbonate units in the Valley and Ridge province. Moreover, because the marble crops out in the axial region of a synclinorium, palinspastic restoration would require that it was deposited 20-30 kilometers oceanward from the Valley and Ridge carbonates, and the fact that it has been transported along with all the underlying rocks along the Carters Dam fault requires an even greater seperation. Thus, it seems unlikely that the Murphy Marble is directly correlative with any of the Valley and Ridge carbonate units, including the "Sylacauga Marble group."

Power and Forrest (1973) interpreted the upper part of the Great Smoky Group (Dean Formation) and the Murphy Group to be in stratigraphic contact. In an eloquent description of the deposits filling one of the Ocoee basins (Murphy basin), they interpreted the Dean Formation to be an alluvial flood-plain deposit, the Nantahala Formation to be a tidal-flat or lagoonal deposit, the Tusquitee Quartzite to be a beach-sand deposit, the Brasstown Formation to be an open-marine shelf deposit, and the Murphy Marble to be a reef or carbonate bank deposit. They stated of the Andrews Formation (Power and Forrest, 1973, p. 707):

> "The calc-schists of the Andrews Formation represent a mixture of carbonate rock with clastic sediments. The carbonate reef of the Murphy marble no longer stood above the level of the surrounding sea floor, and terrestrial material was carried to and across the carbonate bank. There must, therefore, have been general shoaling of the marine shelf on which the Brasstown Formation was deposited."

They went on to interpret the Nottely Quartzite as a beach or off-shore bar deposit that (1973, p. 707) "represents the climax of shoaling and regression of the shoreline that prevailed during deposition of the Andrews Formation." and the Mineral Bluff Formation as marking "a return to open-marine shelf conditions.."

Hurst (1955, p. 8) suggested that a major lithologic and sedimentologic break is present between the uppermost units of the Great Smoky Group and the Nantahala

Formation. We suggest that this break is a thrust fault (detachment took place at the base of the graphitic Nantahala) and that the Murphy Group up through the Murphy Marble is allochthonous to the underlying Great Smoky Group. Our work indicates that some of the garnetiferous schist, quartzite, and amphibolite units that were mapped as Brasstown Formation in the Murphy Group by Fairley (1965) are volcanogenic alteration zones and associated pelagic metasedimentary rocks in the Ropes Creek Metabasalt.

Tull and Guthries' (1983) postulation of an unconformity above the Murphy Marble is a reasonable one, but we follow Power and Forrest (1973), and suggest that the unconformity is located below the Andrews Formation at the very top of the marble (table 2). As Hurst (1955, p. 54), Fairley (1965, p. 30-36), and Power and Forrest (1973, p. 707) pointed out, calcareous schist containing nodules and thin lenses or beds of limonite and (Power and Forrest (1973, p. 707) "a stratigraphic position where brown iron ores have developed" is found above the Murphy Marble, but below higher calcareous schists of the Andrews Formation, suggesting an unconformity. In addition, the marble varies greatly over short distances in thickness (Hurst, 1955, p. 52), and lithologically as well (Hurst, 1955; Fairley, 1965), suggesting that different "subunits" of Murphy Marble have been truncated, and locally completely eroded away. We therefore assign the Nantahala Formation, Tusquitee Quartzite, Brasstown Formation, and Murphy Marble to the Ellijay Group named in Appendix A, and the Andrews Formation, Nottely Quartzite, and Mineral Bluff Formation to the Blue Ridge Group named in Appendix A. The Murphy Group of Hatcher (1972) is abandoned.

Regardless of whether they are allochthonous or not, and what their regional correlations are, the absence of volcanic components in the Ellijay and Blue Ridge Groups indicates that they belong with the Ocoee Supergroup or Chilhowee Group in the Bill Arp thrust sheet. We suggest that they may reside in a separate thrust slice within the Bill Arp sheet. We interpret the Ellijay and Blue Ridge Group rocks to be a sequence of metamorphosed sediments that represent the final infilling of one of the Ocoee basins (see Power and Forrest, 1973, and Bolton, 1985) that formed at the seaward edge of the North American continent during the opening phase of creation of the Iapetus Ocean. Most of the metacarbonate rocks in the crystalline terrane of Georgia and Alabama are probably shelf-like or platform carbonates (see Read, 1985a, 1985b) that formed when the basins were nearly full. We don't think a direct correlation can or should be made between any of the metamorphosed carbonate units (Murphy, "Brevard," Chewacla) in the crystalline terrane in the southernmost Appalachians with units in the Cambrian-Ordovician carbonate shelf sequence in the Valley and Ridge province. They may all be roughly the same age as or slightly older than the carbonate shelf sequence, but they are all transported and probably formed in separate basins (fig. 61). This is probably also true of the Pine Mountain Group; these Great Smoky lithic and depositional equivalents were probably deposited in a different basin from the Great Smoky in the Austell-Frolona anticlinorium, Ola anticlinorium, and the Murphy synclinorium. In fact, the Bill Arp thrust sheet is probably composed of sliced-off remnants of three or more different Ocoee basins. The carbonate units in the Brevard Zone are also considered to be in the Bill Arp thrust sheet, and to represent the same general depositional conditions as the other carbonate units near the top of the Ocoee basins.

Ducktown assemblage

Although the lack of volcanogenic components (including mafic intrusive rocks) is a salient characteristic of the Bill Arp thrust sheet, an exception occurs in the Copperhill Formation, the lowest unit of the Great Smoky Group, along the western flank of the Murphy Syncline west and southwest of McCaysville in northern Georgia (fig. 1). There, both coarse- and relatively fine-grained amphibolites crop out in apparent concordancy with the Copperhill metasedimentary rocks (Hurst,

1955; Slater, 1982, 1985; Abrams, 1985; Slater and others, 1985). Hurst (1955, p. 62-63) considered these rocks to be either "a diabasic or gabbroic sill" that had intruded the Great Smoky metasedimentary rocks, or "thin basalt flows" within the sequence. Abrams (1985) considered the amphibolites to be metadiabase, presumably in dikes. Hurst (1955, p. 63) opted for the sill origin because of metasedimentary inclusions occurring as "large, tabular masses near the center of the sill in the Epworth quadrangle." The amphibolite sill(s) or dike(s) are also present northwest and north of McCaysville in the Copperhill and Ducktown areas, Tennessee (Hurst, 1955; Slater, 1982, 1985; Slater and others, 1985). In all localities the amphibolites appear to be closely associated with thin pyritiferous iron formations and massive sulfide deposits as recognized by Abrams (1985).

In addition to the amphibolite sill(s) and (or) dike(s), fine- to medium-grained metamorphosed felsic tuffs (fig. 10), coarse tuff breccias (fig. 11), and coarse, poorly sorted volcanic-epiclastic conglomerates (fig. 12) occur with the massive sulfide deposits at Ducktown; we call these rocks the Ducktown assemblage. These rocks seem to confirm the volcanogenic nature of the Ducktown deposits (Slater, 1985; Slater and others, 1985). However, rather than being associated directly with thick sequences of volcanic rocks with virtually no nonvolcanogenic metasedimentary rocks, as are the Ropes Creek type and Little River type sulfide deposits (later sections), the massive sulfide deposits in the Ducktown area occur within non-volcanogenic clastic metasedimentary rocks (mostly graywacke and schist - Copperhill Formation) as well as within volcaniclastic and volcanic-epiclastic rocks.

Because they occur in the lowermost part of the Great Smoky Group, in the lowermost metasedimentary rocks in one of the Ocoee basins and partly within nonvolcanic clastic sequences, we follow Slater and others (1985, p. 180-181) and suggest that the metavolcanic and metavolcanic-epiclastic rocks of the Ducktown assemblage represent rift-volcanism associated with the formation of the basin (they appear to be found only around the rift zones). As such, they represent the same early stage of basin formation igneous activity as the Mount Rogers and Grandfather Mountain Formations farther northeast - they mark the beginning stages of extension that resulted in the opening of the Iapetus Ocean.

Zebulon thrust sheet

The next highest thrust sheet in the Georgiabama thrust stack, the Zebulon thrust sheet, is bounded below by the Zebulon thrust fault. Like the Bill Arp sheet the Zebulon sheet underlies large areas in the crystalline terrane of the southernmost Appalachians (fig. 13). The Zebulon sheet is composed of the Zebulon Formation, a thick unit of intercalated, generally pink- to purple-weathering schists (commonly containing abundant aluminosilicate minerals and garnet), ocherous-weathering hornblende-plagioclase amphibolites, and lesser amounts of a wide variety of biotite-plagioclase gneisses (metagraywackes) and minor granitic gneisses (Appendix A). In addition to the intercalated amphibolites, amphibolites also occur as clasts (blocks) in the schists (fig. 14). In its uppermost parts the Zebulon Formation has thin (generally less than a meter thick) beds of gondite (spessartine quartzite) and magnetite-bearing gondite interpreted as metamorphosed volcanogenic chemical sediments. Higgins and Atkins (1971) named this gondite-bearing interval the Senoia Formation, but it has not been mapped separately from the Zebulon Formation in most areas, and is presently considered a member of the Zebulon (Appendix A).

In contrast with the underlying, all-metasedimentary Bill Arp thrust sheet, the Zebulon sheet is an intimate mixture of metavolcanic (including metavolcanogenic sediments) and metasedimentary components. Except in small areas around local shear zones and where the sheet is involved in the retrogression of the

Brevard Zone, the rocks of the Zebulon thrust sheet are at kyanite or sillimanite grade and are not retrograded; the amphibolites are neither chloritized nor otherwise altered.

In Alabama, rocks of the Zebulon thrust sheet have been given various names (table 3), including parts of the Wedowee, Hatchet Creek, Mad Indian, Heard, Jacksons Gap, and Opelika Groups and parts of the Dadeville Complex (Bentley and Neathery, 1970; Neathery, 1975; Sears and others, 1981). Most of the rocks in the Zebulon sheet have not been previously named in Georgia (except for McConnell and Abrams' [1984] assignment of some of the Zebulon to their Univeter Formation - abandoned, see Appendix A). Rocks of the Zebulon thrust sheet crop out over large areas in the Georgia crystalline terrane, from just north of the Towaliga fault zone and just north of the Macon melange, nearly to the Valley and Ridge province (fig. 1). Slices of the Zebulon sheet are found as synformal infolds in the Bill Arp sheet in the Ola and Pine Mountain anticlinoria and in the Murphy synclinorium.

The assemblage of metamorphosed shales, discontinuous mafic tuffs, clasts of basalt, volcanogenic manganese-rich and to a lesser extent iron-rich chemical sediments, and graywackes suggests that the Zebulon may have been an ocean-floor deposit that received clastic material eroded from the Ocoee basins at the edge of the North American continent and volcanic material from the Promised Land island arc. Locally the Zebulon is melange with blocks of amphibolite and (less common) ultramafic rocks in schist.

Clairmont thrust sheet

Locally present above the Zebulon thrust sheet is the Clairmont melange (fig. 2 and 3). The present known distribution of the Clairmont melange in the southernmost Appalachians is shown in figure 15. The Clairmont is a spectacular melange in which fragments, chips, blocks, and slabs of amphibolite (fig. 16a), amphibolite and light-gray granofels (fig. 16b), light- to medium-gray, equigranular biotite granitic gneiss (figs. 16c and a), epidosite, light-gray granofels, metagranite, and "clean" quartzite (fig. 16d) "float" in a polydeformed, locally porphyroclastic but also generally porphyroblastic, streaky to finely layered, locally scaly, light- to dark-gray biotite-plagioclase (± K-feldspar) gneiss matrix. It would be a "type III" melange in Cowan's (1985) recent classification. The matrix also contains autoclastic chips, blocks, and slabs (native blocks - Hsu, 1968). Foliation and folds within all types of clasts (including the autoclastic clasts - fig. 17a) terminate abruptly against the surrounding matrix (figs. 16 and 17). The matrix itself has a tectonic fabric that has ductiley "flowed" around and between some of the more brittle clasts (fig. 18), but the matrix is also pervasively penetrated by innumerable anastomosing, recrystallized shear planes that do not pass into or through the clasts.

The tectonized nature of the matrix and the relation of the matrix to the clasts in the Clairmont melange indicate clearly that it is a tectonic melange, and, because of the matrix textures and the autoclasts, a polykinematic melange. The wide range of clast sizes (from tiny fragments in the matrix to slabs several kilometers long and wide), the fact that folded, multiply folded, and unfolded clasts are present, and the fact that structures within the clasts terminate abruptly against the matrix indicate that these are foreign clasts or "exotic blocks" (Hsu, 1968). The fact that the clast lithologies are nowhere matched by continuous mappable units (even the largest slabs appear to be "floating" in the melange matrix) indicates that the Clairmont is not a simple broken formation or autoclastic tectonic melange formed during emplacement of the overlying thrust sheets. This is supported by the fact that seven or more different rock types representing sedimentary (including rocks probably deposited in very different environments), volcanic, and plutonic protoliths are common as clasts. We have not

been able to lithically match most of the clasts in the Clairmont melange with other units in the Georgiabama thrust stack. However, the interlayered amphibolite and felsic granofels clasts lithically match rocks of the Promised Land thrust sheet. In addition, we mapped several large outcrop areas of rocks that lithically match Wahoo Creek Formation rocks within the Clairmont on the northwest flank of the Newnan-Tucker synform, which we interpret as megaclasts in the melange. Structural features within these masses are discordant to the surrounding melange matrix (foliation in the megaclasts generally has shallow dips whereas foliation of the matrix adjacent to and under them is more steeply dipping). We (Higgins and others, 1984) refer to these megaclasts as the Beaver Ruin slabs (br in fig. 3).

Beneath the main mass of Clairmont melange on the northwestern flank of the Newnan-Tucker synform, but separated from the Clairmont by the Norcross Gneiss granitic sill (fig. 3), is another part of the melange that Higgins and Atkins (1981) named the Inman Yard Formation. This part of the melange, probably more tectonized even than the main mass, belongs with the Clairmont, even though it lacks some of the exotic clasts found in the Clairmont. The basal parts of the melange in the Inman Yard area are mylonitic, contain button schists, and are difficult to separate from adjacent mylonitic rocks of the Brevard Zone. The name Inman Yard Formation is here abandoned.

The variety of clast lithologies in the Clairmont melange and the melanges extremely complex deformational history suggest that it may be the remnant of part of a subduction melange wedge. The amphibolites are interpreted as clasts of Iapetus ophiolite. In the section on evolution of the southernmost Appalachians we interpret the Clairmont melange as the remnant of a subduction melange associated with the volcanic arc in which the rocks in the Wahoo Creek, Atlanta, Promised Land, and Sandy Springs thrust sheets formed.

Wahoo Creek thrust sheet

Structurally overlying the Clairmont thrust sheet is the Wahoo Creek thrust sheet, composed of the Wahoo Creek Formation. The present known distribution of the Wahoo Creek sheet is shown in figure 19. The Wahoo Creek is a unit of varied lithology (Higgins and Atkins, 1981; Wallace, 1981), but consists mainly of thin- and planar- layered, locally laminated, light-gray to nearly white, slabby weathering, fine- to medium-grained muscovite-plagioclase-quartz gneiss, massive but slabby weathering (fig. 20) light-gray to nearly white gneiss with K-feldspar porphyroblasts, and generally lesser amounts of reddish-weathering coarse-grained muscovite schist, and silvery sillimanite-muscovite schist. In many exposures the gneisses have porphyroblasts of K-feldspar and the layered gneiss has layers and lenses of calc-silicate. Thinly layered epidote-hornblende-plagioclase amphibolites are locally common within the layered gneiss (fig. 21). The finely layered nature of some of the gneisses in the Wahoo Creek, and their mineralogic and petrographic characteristics (also see Wallace, 1981), the calc-silicate layers and lenses, and the interlayered amphibolites (metamorphosed mafic tuffs) suggest that part of the Wahoo Creek is a metamorphosed, altered volcaniclastic sediment that has locally been highly tectonized. The more massive gneisses with K-feldspar porphyroblasts may have been granitic plutonic rocks or thick volcaniclastic deposits and the schists were probably volcanic-epiclastic deposits.

The work of Wallace (1981) and of Grant (1958) suggests that what we have mapped and described as the Wahoo Creek Formation is probably several different mappable units (formations). Grant (1958) separated what we call the Wahoo Creek into several different units.

The Wahoo Creek thrust fault is locally exposed; though generally imbricate, it appears to lack much mylonitization.

Atlanta thrust sheet

The composite Atlanta thrust sheet, which structurally overlies the Wahoo Creek thrust sheet, is composed of the (lower) Stonewall slice and the (upper) Clarkston slice (fig. 2). The present known distribution of the Atlanta sheet in the southernmost Appalachians is shown in figure 22. The Stonewall slice is composed of the Stonewall Formation (Higgins and Atkins, 1981) on the northwest limb of the Newnan-Tucker synform (Atkins and Higgins, 1980; fig. 3), and in a smaller outcrop area near the southern end of the synform. Elsewhere, the Stonewall is missing, and the Wahoo Creek thrust sheet is structurally overlain by the Clarkston Formation in the Clarkston slice. The Stonewall Formation consists of medium-grained biotite gneiss and fine-grained hornblende-plagioclase amphibolite, intercalated in various proportions, and lesser amounts of sillimanite-biotite schist.

Structurally overlying the Stonewall slice, or the Wahoo Creek thrust sheet where the Stonewall is missing, is the Clarkston slice, composed of (in ascending structural order) the Ison Branch, Barrow Hill, Clarkston, and Big Cotton Indian Formations (Higgins and Atkins, 1981; Appendix A).

The Ison Branch Formation is a very thinly laminated metamorphosed calcareous tuff (fig. 23) that generally contains 10-20 percent pyrite, as well as trace amounts of other sulfide minerals, and conspicuous graphite. Chaotic folds, interpreted to be soft-sediment slump features (fig. 24) are locally preserved in the metatuff. Small relict flattened pumice is seen in some layers of the metatuff in thin section.

The Barrow Hill Formation overlies the Ison Branch Formation with probable gradational contact. The Barrow Hill is composed of thin layers (less than a meter) of gondite (spessartine quartzite) and magnetite-bearing gondite interbedded with pink- to purple-weathering garnet-sillimanite-muscovite-biotite schists and ocher-weathering hornblende-plagioclase amphibolites. Except for the gondites the Barrow Hill would be identical to the overlying Clarkston Formation. The gondites almost certainly represent distal volcanogenic chemical sediments (manganese-rich, and to a much lesser extent, iron-rich cherts) deposited in a deep-water environment (Stanton, 1976a; Grapes, 1978 - and references in both).

In the Newnan-Tucker synform the Ison Branch and Barrow Hill Formations are present as discontinuous slivers along the base of the Promised Land thrust sheet above the Clarkston slice, indicating either that the Clarkston slice in the Newnan-Tucker synform is inverted in relation to the Clarkston slice in the Griffin synform (fig. 3), or that the thin slivers of Ison Branch and Barrow Hill Formations were sliced off their original positions by the Hannah thrust fault at the base of the Promised Land sheet and emplaced with the Promised Land as it was thrust upon the Atlanta sheet in the Newnan-Tucker synform.

The Clarkston Formation is composed of pink- to purple-weathering sillimanite-garnet-quartz-plagioclase-biotite-muscovite schist (locally slightly graphitic) and ocher-weathering hornblende-plagioclase amphibolite. The schist and amphibolite are generally interlayered on a scale of 1 to 20 meters. In contrast with the Zebulon Formation, which it resembles, amphibolite has not been found as clasts in the Clarkston.

The Big Cotton Indian Formation in the northeast center of the Newnan-Tucker synform is composed of biotite-plagioclase gneisses, hornblende-plagioclase amphibolites, and biotite-muscovite schists. Without the gneisses, the Big Cotton Indian would be similar to the Clarkston, and in fact, it is probably a facies of the Clarkston.

As far as we know, the Clairmont melange, Wahoo Creek, and Atlanta thrust sheets are not found northwest of the Brevard Zone. Many of the rocks in Wahoo Creek and Atlanta thrust sheets are metamorphosed subaqueous volcaniclastic rocks,

but the bulk of the rocks in these sheets are metamorphosed shales with metamorphosed manganiferous volcanogenic chemical sediments characteristic of deep-water deposition. Their association with the volcaniclastic rocks suggests deposition in a back-arc, or more likely an outer-arc basin.

Promised Land thrust sheet

Structurally above the Atlanta thrust sheet is the Promised Land thrust sheet, bounded below by the Hannah thrust fault (figs. 1-3). The present known distribution of the Promised Land sheet is shown in figure 25. The Promised Land sheet is composed entirely of the Promised Land Formation (Higgins and Atkins, 1981). It occupies the axial area of the Newnan-Tucker synform, where it has been thrust upon the Clarkston and Big Cotton Indian Formations of the Atlanta thrust sheet. The Promised Land sheet also underlies a large area northeast of the Newnan-Tucker synform. A thin (less than 3 m) unit of scaly, muscovite-quartz and quartz-muscovite mylonite (mylonite schist), previously called the Hannah Member (abandoned - Appendix A) of the Promised Land Formation (Higgins and Atkins, 1981), is locally mappable along the Hannah thrust fault at the base of the Promised Land sheet.

The Promised Land Formation is composed of various proportions of finely interlayered metamorphosed felsic tuffs and amphibolites (fig. 26), and larger bodies of granitic gneisses. Locally, some of the thicker amphibolite layers are pillowed, but the far more common thin layers were probably mafic tuffs.

The Promised Land thrust sheet is composed entirely of igneous rocks, and consists of about 65-75 percent metamorphosed felsic tuffs, about 5-10 percent granitic metaplutonic or (and) metasubvolcanic gneisses, and about 15-25 percent metamorphosed mafic tuffs and thin flows. The local presence of pillows in some of the metamorphosed flows and the thinly layered nature of the metamorphosed mafic and felsic tuffs indicates that these rocks were mostly deposited subaqueously. The assemblage in the Promised Land is interpreted as representing remnants of a sequence associated with a volcanic arc. As far as we know, the Promised Land sheet is not found northwest of the Newnan-Tucker synform.

Sandy Springs thrust sheet

The next highest thrust sheet in the Georgiabama thrust stack, the Sandy Springs thrust sheet, is bounded below by the Sandy Springs thrust fault. The present known distribution of the Sandy Springs sheet is shown in figure 27. The Sandy Springs thrust fault is exposed at several places (fig. 28). Though folded and metamorphosed, it appears to be a "clean" thrust lacking much mylonitization or brecciation. Hurst (1973) first recognized that the Sandy Springs Group is in thrust contact with the underlying Zebulon Formation (he considered rocks we assign to the Zebulon part of the "Ashland Group"). He also implied that part of the Sandy Springs Group (he labeled it "Sandy Springs?") is present southeast of the Brevard Zone; this was later confirmed by the work of Kline (1980, 1981). The Sandy Springs sheet is composed of the Sandy Springs Group (Higgins and McConnell, 1978), made up of (in ascending order) the Powers Ferry Formation, Chattahoochee Palisades Quartzite, and the Factory Shoals Formation (Appendix A). Higgins and McConnell (1978) included the Rottenwood Creek Quartzite in the Sandy Springs Group. However our remapping has shown that this quartzite is actually the Chattahoochee Palisades Quartzite, so the name Rottenwood Creek Quartzite was abandoned by Higgins and others (1984). Higgins and Atkins (1981) named the Chattahoochee Palisades Quartzite southeast of the Brevard Zone the Lanier Mountain Quartzite Member of the Snellville Formation, and the Powers Ferry Formation the Norris Lake Schist Member of the Snellville Formation. We here abandon the names Snellville Formation, Lanier Mountain Quartzite Member, and Norris Lake Schist Member (Appendix A).

The Powers Ferry Formation is composed of biotite-plagioclase gneisses (metagraywackes), aluminous schists that commonly contain garnet, and lesser amounts of intercalated amphibolites. The Chattahoochee Palisades Quartzite is a kyanite-, or staurolite-, or sillimanite-bearing, and generally garnet-bearing, quartzite or muscovite-quartz schist. The Factory Shoals Formation is composed mainly of aluminous (kyanite-, or staurolite-, or sillimanite-bearing) garnet-biotite-muscovite schist with intercalated thin metagraywackes and less common graphitic micaceous quartzites and quartz schists.

Detrital zircons from the Chattahoochee Palisades Quartzite at two localities have yielded Grenville-age U-Pb dates (T.W. Stern, oral commun. Sept., 1984). This indicates that the source for some of the sediments in the Sandy Springs Group was Grenville-age basement, thus placing constraints on assignment of the Sandy Springs rocks in developmental models for the southernmost Appalachians.

Northwest of the Brevard Zone and the Newnan-Tucker synform, rocks of the Sandy Springs Group are tightly folded with higher and lower thrust sheets, but southeast of the Brevard and east and northeast of the Newnan-Tucker synform, the Chattahoochee Palisades Quartzite caps low ridges, and where streams have cut through these ridges they have cut through the Sandy Springs thrust sheet and into underlying thrust sheets. Although isoclinally folded before or (and) during thrust emplacement, the rocks of the Sandy Springs sheet and higher sheets southeast of the Brevard Zone appear less deformed than northwest of the Brevard; the difference in deformation is discussed in a later section.

Paulding thrust sheet

Structurally above the Sandy Springs thrust sheet is the Paulding thrust sheet, bounded below by the Paulding thrust fault (fig. 2). The present known distribution of the Paulding sheet in the southernmost Appalachians is shown in figure 29. The Paulding sheet is composed of the Paulding Volcanic-Plutonic Complex (Appendix A), made up of light-green-weathering, epidote-rich, generally chloritic, green or blue-green hornblende- or (and) actinolite-plagioclase amphibolites (about 50-60 percent) intimately interlayered with light-gray to nearly white, amphibole-bearing granofels and biotite-bearing gneisses (metamorphosed felsic and intermediate tuffs - about 20-30 percent). Dikes, sills, and small plutons of K-feldspar-poor granitic rocks and K-feldspar-bearing granitic rocks (fig. 30) are ubiquitous and numerous (about 15-20 percent), and pods of epidosite are common. Thin layers and lenses of vermiculitic mica (not included in the percentages) are locally present, but their protolith is unknown. A distinctive siliceous and spongy "hardpan" is generally found above the rocks in the Paulding sheet. The Paulding sheet is essentially an all-igneous sheet, devoid of clastic metasedimentary rocks. This lack of clastic metasedimentary rocks, coupled with its distinctive appearance in outcrop, and the fact that its mafic rocks are generally epidotic and chloritic, distinguishes it from underlying thrust sheets.

Rocks of the Paulding thrust sheet have been given various names in Alabama (Bentley and Neathery, 1970; Neathery, 1975; Tull and others, 1978; Stow, 1982; Stow and others, 1984), including Waresville amphibolite (abandoned) and the lower part of the Hillabee greenstone (informal, see Hillabee greenstone under Ropes Creek thrust sheet); we include these rocks in the Paulding Volcanic-Plutonic Complex (Appendix A). In Georgia, the Waresville Amphibolite (abandoned) of Bentley and Neathery (1970) is included in the Paulding Complex, as are parts of the Pumpkinvine Creek Formation of McConnell (1980; abandoned), and the New Georgia Group (abandoned) of Abrams and McConnell (1981) and McConnell and Abrams (1984).

The fact that the Paulding sheet is made up of metavolcanic and metaplutonic rocks, including intermediate and felsic tuffs, and the lack of nonvolcanic sedimentary rocks indicates that this assemblage formed in an island arc. This

assignment is supported by the geochemical characteristics of some of the rocks in the Paulding thrust sheet (Stow, 1982, "Millerville samples" for example; Stow and others, 1984; Appendix B).

West Point thrust sheet

The next highest thrust sheet is composed of the remnants of an ophiolitic melange, which we here name the West Point melange from the locality where it was discovered by Sears and others (1981) along the shores of West Point Reservoir behind West Point Dam on the Chattahoochee River about 4 km northeast of Lanett, Alabama. It would be mostly a "type III" melange in Cowan's (1985) classification. Outcrops of the melange are relatively rare, probably because of tectonic elimination, and where it is found (fig. 1) it is commonly located structurally beneath, and folded with, the Ropes Creek Metabasalt in the Ropes Creek thrust sheet. The present known distribution of the West Point thrust sheet is shown in figure 31, but the West Point may be present in many other areas of Ropes Creek outcrop.

Sears, Cook, and Brown (1981, p. 5) described the West Point Reservoir occurrence as follows:

> "East of West Point Dam, along the shore of West Point Lake, at low water, there are magnificently exposed several hundred bodies of hornblende gneiss, metagabbro, dunite, chlorite schist, pyroxenite, talc, olivine pyroxenite, layered olivine-pyroxene rock, garnet chlorite gneiss, anthophyllite schist and minor felsic gneiss floating in a matrix of chloritic schist laced with pegmatites. The bodies occur in a unit at least 100 m thick and continuously exposed along strike for 2 km. The bodies are generally well-rounded, some being perfectly spherical, and are up to 4 m in diameter. Grossly different lithologies are commonly adjacent to one another, along the same foliation trend. Layering in some bodies is truncated at the edges at an angle to the matrix schistosity. Very coarse chlorite masses sheath some of the bodies. Ultramafic bodies have rinds of talc and anthophyllite separating them from the matrix."

Our work indicates that the melange is also present around and below (downstream from) West Point Dam, and also along the western shore of the Reservoir. Thus, we suggest that as much as a kilometer thick section of melange is preserved in the West Point Dam area.

The West Point melange is also preserved beneath the small mafic bodies near Marble Hill, Georgia (fig. 1), that were mapped as metagabbro by Fairly (1965, 1969). The mafic bodies are probably small slices of locally amygdular Ropes Creek Metabasalt (fig. 32). Near the northwestern end of the largest slice (see Fairly, 1965, plate 1) several tens of meters of the melange is preserved beneath the Ropes Creek Metabasalt. Here, the melange matrix is a scaly, highly deformed micaceous schist containing isolated clasts, as large as about 10 meters, of altered ultramafic and mafic rocks. Contacts of the clasts with the matrix are sharp, and the matrix appears to have "flowed" around the clasts (fig. 33). The smaller slice to the west is made up almost entirely of melange, at least 100 meters thick, that is literally crowded with a variety of mafic and ultramafic rocks. The mafic rocks are mostly gabbro, and the ultramafic rocks are now mostly serpentinite, talc, and chlorite-actinolite schist. We have not yet mapped these occurrences in sufficient detail to completely outline the melange, so its total thickness is unknown.

Perhaps the most striking outcrops of the West Point melange are in the unit in northeast Georgia that Hartley (1973) and Hartley and Penley (1974) mapped as the "Lake Chatuge Sill" west and southwest of Hiwassee, Georgia, and in a similar

occurrence along the northeastern shore of Lake Chatuge north of Hiwassee (fig. 1) that has been called the "Shooting Creek Complex" (Hatcher and others, 1984). The melange in this area is probably at least several hundred meters thick, and may be more than a kilometer thick. What were mapped as sills are Ropes Creek Metabasalt and West Point melange (thrust sheets) that are intimately folded together. A large slice of the Zebulon thrust sheet is present beneath the melange, or beneath the Ropes Creek where the melange is absent. The sill-like map pattern results from erosion through the arched thrust sheets into very erosion-resistent rocks of the Great Smoky Group (Bill Arp thrust sheet) that underlie Brasstown Bald, the highest mountain in Georgia. In the window, contacts between the Great Smoky units (Copperhill and Wehutty Formations) trend northeast in contrast with the nearly north-south elongation of the map pattern of the West Point melange and Ropes Creek thrust sheets.

The matrix of the West Point melange in the Lake Chatuge area is highly sheared and deformed talc-actinolite-chlorite schist (with clumps of relict olivine) and (or) highly deformed amphibolite (fig. 34); small anastomosing fault planes are ubiquitous and oriented in many directions (fig. 35). A wide variety of mafic and ultramafic rocks (including dunite, coronite troctolite, olivine gabbro, and wehrlite) occur as clasts (blocks) in the matrix (fig. 36). However, the most significant clasts are of eclogite (Kellberg, 1943; Hartley, 1973; Dallmeyer, 1974). In most localities knockers of eclogite and (or) of well-foliated (locally metamylonitic) amphibolite containing clasts of eclogite (fig. 37) form low knobs above the surrounding more easily eroded matrix, and locally it can be demonstrated that the eclogites are clasts surrounded by the matrix (fig. 38).

Dallmeyer's (1974) study of the eclogites in the West Point melange showed: (1) that their chemical compositions fall in the range of eclogites from "alpine-type terranes (glaucophane schists)" on an F-M-A diagram; (2) that the chemical compositions of cores of their garnets fall into the field of "glaucophane schists" on an Al+Sp-Gr+ And-Py diagram; and (3) that the primary cores of their pyroxenes fall well in the "eclogite field" as opposed to the "granulite field" on a plot of jadite against Cats and on a (Di+Hed+En)-(Jd)-(Cats) diagram. Other aspects of Dallmeyer's study suggest that the eclogites have been slightly retrograded; however he stated (1974, p. 372):

> "The skeletal clinopyroxene inclusions in garnet led Hartley (1973) to infer that the garnet is secondary and developed during Middle Paleozoic metamorphism of the Lake Chatuge peridotite. The chemical data presented here are inconsistent with this interpretation, for both the inclusions and the cores of primary clinopyroxene grains are jadeitic. This implies a high pressure origin. Also, the configuration of core tie-lines suggests that garnet and clinopyroxene are cogenetic."

Dallmeyer (p. 373) concluded, based on available experimental data, that the eclogites formed at pressures between 15 and 20 kb and temperatures between 1000-2000 degrees C.

Jones and others' (1973) determinations of present-day Sr^{87}/Sr^{86} ratios from rocks of the West Point melange and Ropes Creek Metabasalt in the Lake Chatuge area range from 0.7023 to 0.7047 indicating "upper-mantle" derivation (more likely oceanic crust derivation). More recently, Shaw and Wasserburgs' (1984) analyses of Nd and Sr and Sm-Nd isotopes from Ropes Creek Metabasalt in the Lake Chatuge area and from the Chunky Gal Mountain "mafic-ultramafic complex" (McElhaney and McSween, 1983) along strike in North Carolina (probably Ropes Creek and Soapstone Ridge thrust sheets; West Point melange does not appear to be present in the complex), led them to conclude (1984, p. 341) that "the Chunky Gal and Lake Chatuge amphibolites clearly have the isotopic signature of ancient oceanic crust."

The West Point melange is also preserved beneath Ropes Creek Metabasalt that has been considered Hillabee greenstone around Needmore, Alabama (fig. 1). In that area, "knockers" of pyroxene-garnet-chlorite rock (probably retrograded eclogite) form low knobs above the lowland underlain by the chloritic and talcose matrix. Metachert and a variety of mafic and ultramafic rocks are found as scattered float in the melange (also see Prouty, 1923).

With the exception of glaucophane schists (which probably would not have survived the amphibolite-grade metamorphism imposed on the West Point melange during its transport and emplacement; see Ernst, 1972), eclogites are generally regarded as prime indicators of subduction melange (for example; Ernst, 1972, Hamilton, 1979). Their presence, along with a wide variety of oceanic crust and mantle type igneous rocks in a highly sheared and altered mostly mafic matrix in the West Point melange indicates quite strongly that the West Point is the remnant of an ancient subduction melange complex, preserved beneath the Iapetus Ocean crust and mantle in the Ropes Creek thrust sheet that was obducted upon it.

Ropes Creek thrust sheet

Structurally above the West Point melange, or (more commonly) above the Paulding thrust sheet or lower units where the melange has been tectonically eliminated, is the Ropes Creek thrust sheet, composed of the Ropes Creek Metabasalt (Ropes Creek Amphibolite of Bentley and Neathery, 1970 - see Appendix A) and its Cedar Lake Member, and mostly unnamed, but mappable (fig. 3), volcanogenic alteration zones and iron formations, and the Canton Schist (a named alteration zone). The present known distribution of the Ropes Creek sheet in the southernmost Appalachians is shown in figure 39. The Ropes Creek thrust sheet is essentially devoid of nonvolcanic clastic sedimentary rocks as also recognized by Fleming and others (1980), though pelagic manganiferous schists are locally present. Named units assigned to the Ropes Creek Metabasalt in Alabama include the Mitchell Dam, Ropes Creek, Beaverdam, and Ketchepedrakee amphibolites, part of the Doss Mountain amphibolite, the Slaughters Metagabbro, and the upper part (nearly all) of the Hillabee greenstone (Bentley and Neathery, 1970; Neathery, 1975; Tull and others, 1982; Stow, 1982; Neilson, 1983; Stow and others, 1984; These names are considered informal - Appendix A), and in Georgia, most of the Pumpkinvine Creek Formation (McConnell, 1980) - name abandoned (Appendix A), and the Lost Mountain Amphibolite Member of the Univeter Formation (McConnell and Abrams, 1984) - names abandoned (Appendix A).

The Ropes Creek Metabasalt is composed of ocher-weathering, massive to finely layered, locally laminated, locally pillowed (fig. 40), locally chloritic, commonly garnetiferous, locally magnetite-bearing, generally pyrite-bearing, green to greenish-black, hornblende-plagioclase and plagioclase-hornblende amphibolites with insignificant amounts (generally less than a very small fraction of a percent) of fine- to medium-grained, generally amphibole-bearing granofels. The final weathering product of the amphibolites is a very characteristic dark-red clayey soil. The mafic rocks of this sheet are at least partially chloritized and (or) epidotized; few areas over a few square kilometers have escaped some chloritization, epidotization, or uralitization. Many of the rocks in the Ropes Creek sheet contain disseminated pyrite, and locally, highly pyritiferous zones, as much as 20 meters wide can be followed for as much as a hundred meters along strike. The Ropes Creek thrust sheet also contains various K-feldspar-poor granitic rocks, including trondhjemites (Pate, 1980; Sanders, 1983), that are locally associated with gold-bearing quartz veins and alteration zones.

One of the more distinctive features of the Ropes Creek thrust sheet is that it contains a diverse suite of iron-rich, siliceous, and manganiferous metavolcanogenic, largely exhalative, chemical metasediments, divided (terminology modified

from Stanton, 1976b) into banded iron formations (Abrams and McConnell, 1982; McConnell and Abrams, 1983, 1984; Abrams, 1985), ironstones, magnetite quartzites (Pate, 1980), manganiferous quartzites, and manganiferous schists (fig. 41). Some of the manganiferous rocks are similar to those found in the Zebulon and Atlanta thrust sheets, but the iron-rich rocks are so characteristic of the Ropes Creek thrust sheet that they can be used almost like index fossils to identify it. Locally associated with the iron-rich rocks are thin layers of fibrous tourmaline (generally dravite). In addition, as far as we know (except for sulfide deposits in the Little River allochthon [see Bell, 1982] and Ducktown-type deposits [see Slater and others, 1985]), all of the massive volcanogenic sulfide deposits in Georgia and Alabama are within the Ropes Creek thrust sheet and are closely associated with the iron formations (Pate, 1980; McConnell and Abrams, 1982, 1984; Abrams and McConnell, 1984) and tourmaline layers (or tourmalinite, also see Slack, 1982) in mappable linear, siliceous and (or) aluminous, graphitic, magnetite-, garnet-, and pyrite-rich (fig. 42) alteration zones (fig. 3, for example) that were probably closely associated with submarine exhalative vents (also see Carpenter and Allard, 1982, and Allard and others, 1985).

Geochemical studies (Stow and others, 1984; Appendix B) indicate that the amphibolites in the Ropes Creek thrust sheet probably originated as seafloor basalts in an oceanridge type environment. Isotopic studies (Jones and others, 1973; Shaw and Wasserburg, 1984 - see section on West Point melange) also indicate that the Ropes Creek amphibolites are ancient oceanic crust. These interpretations are supported by the fact that the rocks in the Ropes Creek thrust sheet are almost entirely mafic (though ultramafic rocks and insignificant amounts of intermediate to felsic rocks also occur), contain volcanogenic sulfide-rich alteration zones and deposits (probably "black-smoker" deposits), and are associated with metavolcanogenic chemical sediments (iron-rich and, to a slightly lesser extent, manganese-rich cherts) and minor amounts of manganiferous and (or) graphitic pelagic sediments. We suggest that most of the rocks in the Ropes Creek thrust sheet originated at the mid-Iapetos Ridge.

Hillabee greenstone (informal)

"Hillabee greenstone" has been used for a sequence of metavolcanic and lesser metaplutonic rocks whose lower part belongs to the Paulding Volcanic-Plutonic Complex in the Paulding thrust sheet, and whose upper part, which makes up almost all of its outcrop belt, belongs to the Ropes Creek Metabasalt in the Ropes Creek thrust sheet; West Point melange is locally present beneath the Ropes Creek Metabasalt. The Hillabee has most recently been considered to rest stratigraphically and conformably upon the fossiliferous Lower and Middle Devonian Jemison Chert at the top of the Talladega Group (Tull and others, 1978; Tull and Stow, 1980a, 1980b; Tull, 1982; Stow, 1982 - the Talladega Group is discussed in a later section). We disagree with this interpretation for several reasons: (1) Everyplace we have examined the contact between the Hillabee and the Jemison, or between the Hillabee and Jemison equivalents, it appears to be a thrust fault (locally imbricate) that has placed the low-grade Hillabee upon the low-grade Talladega Group. In some places the Paulding Volcanic-Plutonic Complex rests upon the metasedimentary rocks, in others the West Point melange rests upon these rocks, and in most places the Ropes Creek Metabasalt rests upon them; (2) The upper part of (most of) the Hillabee has <u>all</u> of the distinctive characteristics that are unique to the Ropes Creek thrust sheet in Georgia and Alabama. It is an almost entirely metaigneous unit (but includes pelagic manganiferous sediments, volcanogenic chemical sediments, and volcanogenic alteration zones) that is lithologically identical to the Ropes Creek Metabasalt (including the Mitchell Dam amphibolite and Ketchepedrakee amphibolite, which are relatively nearby to the south). The

distinctive banded iron formations, ironstones, and magnetite quartzites that are unique to the Ropes Creek thrust sheet are widespread within the upper (Ropes Creek) part of the Hillabee. The Ropes Creek part of the Hillabee has the same type massive volcanogenic sulfide deposits (Stow and Tull, 1982) that are confined to the Ropes Creek sheet. The mafic rocks of the Hillabee show the same chloritization, epidotization, and uralitization as mafic rocks in other parts of the Ropes Creek sheet, and many have the same disseminated pyrite (Tull and others, 1978, p. 19) and pyritiferous zones as mafic rocks in other parts of the Ropes Creek sheet; (3) The distinctive eclogite-bearing West Point melange is present beneath the Ropes Creek part of the Hillabee around Needmore, Alabama (fig. 1), and probably elsewhere (Prouty, 1923); (4) Comparison of the geochemical data in Stow and others (1984) from the Ropes Creek Metabasalt (including the Mitchell Dam and Beaverdam amphibolites, and most of the Ketchepedrakee amphibolite) and from the Paulding Volcanic-Plutonic Complex (including the Waresville Amphibolite) with the geochemical data in Tull and others (1978), Tull and Stow (1980a, 1980b), and Stow (1982) from the Hillabee greenstone (mostly Ropes Creek Metabasalt, but locally including rocks of the Paulding Volcanic-Plutonic Complex in its lower parts, especially around Millerville, Alabama) clearly shows the identical chemical composition of the upper and lower parts of the Hillabee and the Ropes Creek Metabasalt and Paulding Complex (Appendix B); (5) The unpublished map of the Crystalline Rocks of Alabama (Alabama Geological Survey, 1973), and Tull and others' (1978) maps of the internal stratigraphy of the Hillabee suggest that part of the Hillabee section is locally cut out against Talladega Group units by the basal Paulding thrust fault; (6) Zircons from felsic units within the Paulding part of the Hillabee have yielded Ordovician ages of about 460 m.y. (Russell, 1978, Russell and others, 1984) - the zircon data are slightly discordant and the crystallization age could be older (but probably not younger - see Russell and others, 1984); (7) Variations in degree of deformation and metamorphism of the Jemison Chert in the vicinity of Jemison, Alabama, were probably caused by overthrusting of the Hillabee upon the Jemison. West of the town of Jemison, where the Hillabee probably is not in contact with the Jemison Chert (Coastal Plain sediments partially obscure the relationship), but is several kilometers to the south of the chert (also see Sutley, 1977), the Jemison is unsheared, unmetamorphosed, and contains a diverse suite of undeformed fossils. In contrast, only a few kilometers to the east the Jemison has been transformed into a sheared, strongly foliated, clearly metamorphosed micaceous quartzite and quartz-rich phyllonite (also see Tull, 1982, p. 11-12). A slight sedimentary facies change occurs in the Jemison through the same interval -- microconglomerates with small chips of chert appear a short distance east of the town of Jemison, and the unit also becomes more micaceous. The change in the Jemison Chert from an unsheared, unfoliated, unmetamorphosed chert with an interlocking mosaic texture of microquartz and chalcedony (also see Tull, 1982) to a well-developed tectonite with sheared and strongly foliated textures takes place a little farther to the east, almost exactly where the Hillabee first rests directly upon the Jemison, and becomes still more marked farther to the east. We suggest that the deformation and metamorphism of the Jemison Chert is directly related to and probably caused by thrust emplacement of the Hillabee greenstone upon the thin chert unit; (8) Original facies differences between the Hillabee metavolcanic rocks and the structurally underlying Jemison Chert strongly favor fault emplacement of the Hillabee. Geochemical and petrologic studies (Tull and others, 1978; Tull and Stow, 1980a, 1980b; Stow, 1982) indicate that the dominately mafic Hillabee has affinities with both <u>low-K tholeiitic island arc basalts</u> (the lower part [around Millerville, Alabama] belonging to the Paulding Volcanic-Plutonic Complex) and <u>ocean floor basalts</u> or "abyssal tholeiites" (the upper part belonging to the Ropes Creek Metabasalt). According to Tull and Stow (1978), the data eliminate within plate

basalts as parental material for any part of the Hillabee. Stow (1982, p. 90) stated:

> "...the low K_2O content of Hillabee tholeiites compared with that of typical island arc tholeiites (0.25% versus 0.44%; Jakes and White, 1973) can be interpreted to indicate minimal, continental crustal influence during volcanism."

In sharp contrast, the lithologies and the faunal assemblage of the Jemison Chert indicate that it is a shallow-water deposit more akin to the continental Valley and Ridge rocks (in fact it is the Armuchee Chert-Frog Mountain Sandstone sequence) than to the rocks of the crystalline terrane; the Jemison must have been deposited on continental crust, and it has a faunal assemblage quite similar to that of nearby Valley and Ridge province rocks. Therefore, it seems highly improbable that island arc, and ocean floor material, with little or no evidence of continental crustal contribution, represented by the Hillabee greenstone, could have developed near to and been conformably deposited upon the thick pile of clastic metasedimentary rocks of the Talladega Group, which appear to be essentially devoid of volcanogenic material; and (9) The general absence of volcanic material in the Upper Devonian Chattanooga Shale* and Lower Mississippian Maury Shale in the Valley and Ridge province less than 10 kilometers north and northwest of the Hillabee and the Jemison Chert-Butting Ram Sandstone (Butts, 1926; Conant and Swanson, 1961; Thomas, 1979; Smith, 1979) is strong evidence against an island arc built stratigraphically above the Lower and Middle Devonian Jemison Chert-Butting Ram Sandstone.

Our work indicates that the Hillabee greenstone in the Alabama crystalline terrane is simply the northwesternmost infold of the Ropes Creek and (or) Paulding thrust sheets (and locally the West Point melange), that it originated a long way from its present position structurally atop the Talladega Group, and that its lower Paulding part is probably no younger than Middle Ordovician. Because evidence presented in later sections indicates that it was already emplaced upon lower sheets in the stack by the time of the unconformity that truncates part of the Upper Cambrian and Lower Ordovician Knox Group, we suggest that the Hillabee (and all of the Ropes Creek and Paulding thrust sheet rocks) is mostly Cambrian in age.

Soapstone Ridge thrust sheet

Structurally above the Ropes Creek thrust sheet is the Soapstone Ridge thrust sheet, the highest sheet in the Georgiabama thrust stack (fig. 2). It occurs as widely scattered remnants throughout the crystalline terrane northwest of the Macon melange (fig. 43), either because of erosion or because the sheet may have broken up during transport and emplacement, or, more likely, both. Named units in the Soapstone Ridge thrust sheet in Alabama include the Goodwater and Boyds Creek ultramafic-mafic complexes (informal), and part of the Doss Mountain amphibolite and Slaughters gabbro (Bentley and Neathery, 1970; Reynolds, 1973; Neathery, 1975; Nielson, 1983), and in Georgia, the Soapstone Ridge and Laurel Creek Complexes (Higgins and others, 1980; Higgins and Atkins, 1981; Hatcher and others, 1984).

Like the Ropes Creek, Paulding, and Promised Land thrust sheets, the Soapstone Ridge is essentially an entirely igneous thrust sheet, but most of the rocks in this sheet are "metaplutonic" rather than metavolcanic. The Soapstone Ridge sheet is composed of ultramafic-mafic complexes and of small ultramafic and (less common) mafic slices. The ultramafic-mafic complexes commonly have a relatively thin basal unit of dunite or (and) peridotite that has been sheared and altered to serpentinite and talc-chlorite schist. The basal unit is commonly overlain either by mixed

* Conant and Swanson (1961, p. 30-34) reported a thin (1.5-4.3 cm) bentonite bed in the Chattanooga Shale in Tennessee, but indicated that it is not present in Alabama.

units of altered ultramafic rocks and uralitized and chloritized metagabbroic rocks (including metagabbros, metatroctolites, meta-anorthosites, etc.), or by uralitized and chloritized metapyroxenites, or by both assemblages.

One of the largest of the ultramafic-mafic complexes, the Soapstone Ridge Complex, has small sheeted-dike swarms (Higgins and others, 1980; H.E. Cofer, oral commun., 1984), and locally rests upon thin slices of the Ropes Creek and Paulding thrust sheets (fig. 3). Its basal thrust fault is well exposed at several places (fig. 44), and where it rests upon rocks of the Promised Land thrust sheet it truncates folds, pegmatites, and quartz veins in the underlying rocks.

The work of Bluhm and Zimmerman (1977) and Dribus and others (1977) on small ultramafic-mafic complexes that are probably part of the Soapstone Ridge thrust sheet northwest of the Brevard Zone in North Carolina indicates that they have mantle-derived fabrics. Hatcher (1978), and Hatcher and others (1981, 1984) recognized that some of the small ultramafic-mafic complexes in North Carolina and northern Georgia rest in thrust contact on the underlying rocks and are probably ophiolite-related.

We suggest that many of the small ultramafic and less common ultramafic-mafic bodies scattered through the crystalline terrane of the southernmost Appalachians are ophiolitic and part of the Soapstone Ridge thrust sheet. Some of these small bodies are clearly thrust-emplaced, but for most there is little evidence to indicate their mode of emplacement. However, the work of Prowell (1972) indicates that many of the small ultramafic bodies southeast of the Brevard Zone in Georgia were cold when emplaced in their present positions.

Numerous small altered ultramafic bodies that have been mined for talc in the vicinity of Fort Mountain in northwest Georgia (Hopkins, 1914; Furcron and others, 1947; Needham, 1972) are especially important because of their location (fig. 1) near the cratonward edge of the crystalline terrane (see section on "Hayesville fault"). These bodies are now composed mainly of talc and serpentinite, but they contain chromite and pyrite, and some are intimately associated with greenstone. They occur imbricated with slices of sheared Corbin Gneiss and massive microconglomerates of the Pinelog Formation (fig. 45). These altered ultramafic rocks are very likely remnants of the Soapstone Ridge thrust sheet, and as such are the most cratonward remnants of that sheet. Their occurrence intershingled with Fort Mountain Gneiss of the Grenville basement indicates that this part of the Soapstone Ridge thrust sheet (or pieces of it) was emplaced directly upon the Bill Arp thrust sheet.

Wolf Creek Formation

Southeast of the Brevard Zone and northeast of the Newnan-Tucker synform (fig. 3) is a unit of low grade-appearing button schists, phyllonites, and fine-grained, thinly laminated, commonly sheared amphibolites that Higgins and Atkins (1981) named the Wolf Creek Formation. We have not yet mapped the Wolf Creek northeast of the area of figure 3, but reconnaissance shows that it extends at least another 20 kilometers. The rocks of the Wolf Creek have been considered part of the Brevard Zone (Crickmay, 1939, Grant, 1949); our interpretation of the Brevard Zone (see below) agrees well with this assignment for the Wolf Creek. The Wolf Creek Formation is structurally overlain by the Clairmont thrust sheet and has been thrust upon Bill Arp thrust sheet rocks in the Brevard Zone, so it belongs tectonostratigraphically with the Zebulon thrust sheet. The button schists, phyllonites, and fine-grained amphibolites of the Wolf Creek probably represent sheared schists, biotite gneisses (metagraywackes), and amphibolites of the Zebulon Formation.

Summary Table

Summaries of some of the salient characteristics of the thrust sheets in the Georgiabama thrust stack are given in table 3.

Table 3. Summaries of the thrust sheets in the Georgiahama thrust stack.

Table 3a. Summary of the Bill Arp thrust sheet.

Overlain by the Zebulon thrust sheet

STRUCTURAL UNITS	STRATIGRAPHIC OR (AND) TECTONOSTRATIGRAPHIC UNITS	GENERAL CHARACTERISTICS
Bill Arp thrust sheet, Richard Russell thrust slice, and Blue Ridge thrust slice.	**Grenville basement:** Allatoona Complex (Corbin Gneiss), Wachoochee Complex (Woodland Gneiss, Cunningham Granite and Sparks Schist), Wiley Gneiss. **Ocoee Supergroup:** Great Smoky Group (Russell Gneiss, Copperhill, Ola, Kalves Creek, Frolona, Wehutty, Hughes Gap, Bill Arp, Hothouse, and Dean Formations); Pine Mountain Group (Hollis Quartzite, Manchester Schist, Mountain Creek Formation, Chewacla Marble); Ellijay Group (Mantahala Formation, Tusquitee Quartzite, Brasstown Formation, Murphy Marble); Blue Ridge Group (Andrews Schist, Hottely Quartzite, and Mineral Bluff Formation). Chilhowee Group (Cochran, Nichols, Wilson Ridge, and Weisner Formations). Parts of the Wedowee, Hatchet Creek, Mad Indian, Heard, Jacksons Gap, and Opelika Groups, and the Moffits Mill Complex of Bentley and Neathery (1970).	Poorly sorted fan deposits passing upwards into better sorted basin-fill deposits, beach deposits, and carbonate platform deposits. Schists and graywackes in lower parts are generally rich in TiO_2 and Al_2O_3.

INTERPRETED ORIGIN

Autochthogenetic rift-basin fill assemblages.

Lowermost sheet in the thrust stack

Table 3b. Summary of the Zebulon thrust sheet.

Overlain by the Clairmont thrust sheet

STRUCTURAL UNITS	STRATIGRAPHIC OR (AND) TECTONOSTRATIGRAPHIC UNITS	GENERAL CHARACTERISTICS
Zebulon thrust sheet.	Zebulon Formation and its Senoia Member, parts of the Wedowee, Hatchet Creek, Red Indian, Heard, Jacksons Gap, and Opelika Groups (Bentley and Neathery, 1970), part of the Dadeville Complex (Bentley and Neathery, 1970).	Interlayered and intercalated hornblende-plagioclase amphibolites and pink-purple-weathering, generally aluminosilicate-bearing schists with variable amounts of biotite-plagioclase gneisses and granitic gneisses. In many places amphibolites occur as blocks (clasts) in the schists. Manganiferous quartzites (gondites - metamorphosed cherts) are common in the upper parts of the unit.

INTERPRETED ORIGIN

Allochthonous ocean floor assemblage; pelagic sediments, distal volcanogenic sediments, basaltic tuffs, and blocks of basalt shed as debris from higher thrust sheets. Probably deposited in a large back-arc basin or small ocean basin.

Underlain by the Bill Arp thrust sheet

Table 3c. Summary of the Clairmont thrust sheet.

Overlain by the Wahoo Creek thrust sheet

STRUCTURAL UNITS	STRATIGRAPHIC OR (AND) TECTONOSTRATIGRAPHIC UNITS	GENERAL CHARACTERISTICS
Clairmont thrust	Clairmont melange (Clairmont	Polymictic, polykinematic melange with clasts of many sizes of many different rock types. Some of the clasts are lithic matches of rocks in overlying thrust sheets.

INTERPRETED ORIGIN

Allochthonous subduction melange assemblage; probably the upper part of the melange wedge associated with the Promised Land island arc.

Underlain by the Zebulon thrust sheet

Table 3d. Summary of the Wahoo Creek thrust sheet.

Overlain by the Atlanta Thrust sheet

STRUCTURAL UNITS	STRATIGRAPHIC OR (AND) TECTONOSTRATIGRAPHIC UNITS	GENERAL CHARACTERISTICS
Wahoo Creek thrust sheet	Wahoo Creek Formation	Composed of a wide variety of metavolcanic, metavolcanic-epiclastic, and metaplutonic rocks, but mainly of thin- and planar-layered, light-gray to nearly white, slabby weathering muscovite-plagioclase-quartz gneiss with K-feldspar porphyroblasts, and generally lesser amounts of reddish-weathering coarse-grained muscovite schist and silvery sillimanite-muscovite schist. Thinly layered epidote amphibolites and calc-silicate rocks are widespread in all lithologies.

INTERPRETED ORIGIN

Allochthonous island arc assemblage; mostly metamorphosed altered felsic and siliceous volcaniclastic rocks and their hypabyssal equivalents formed in the Promised Land island arc.

Underlain by the Clairmont thrust sheet

Table 3e. Summary of the Atlanta thrust sheet.

Overlain by the Promised Land thrust sheet

STRUCTURAL UNITS	STRATIGRAPHIC OR (AND) TECTONOSTRATIGRAPHIC UNITS	GENERAL CHARACTERISTICS
Clarkston and Stonewall slices.	Stonewall, Ison Branch, Barrow Hill, Clarkston, and Big Cotton Indian Formations.	Stonewall slice: medium-grained biotite gneiss and fine-grained hornblende-plagioclase amphibolite intercalated in various proportions, and lesser amounts of sillimanite-biotite schist. Clarkston slice: Ison Branch Formation: metamorphosed, finely laminated, calcareous, pyritic felsic tuff. Barrow Hill Formation: gondite (spessartine quartzite) interlayered with pink-purple-weathering schist and amphibolite. Clarkston Formation: interlayered pink- to purple-weathering schist and amphibolite. Big Cotton Indian Formation: biotite-plagioclase gneisses, hornblende-plagioclase amphibolites, and biotite-muscovite schists in various proportions.

INTERPRETED ORIGIN

Allochthonous island arc and outer-arc basin assemblage; volcaniclastic rocks mixed with pelagic sediments, volcanogenic chemical sediments, and clastic sediments from Sandy Springs microcontinent.

Underlain by the Wahoo Creek thrust sheet

Table 3f. Summary of the Promised Land thrust sheet.

Overlain by the Sandy Springs thrust sheet

STRUCTURAL UNITS	STRATIGRAPHIC OR (AND) TECTONOSTRATIGRAPHIC UNITS	GENERAL CHARACTERISTICS
Promised Land	Promised Land Formation	Intercalated thin hornblende-plagioclase amphibolites (15-25%) and felsites (65-75%), with local granite gneiss bodies (5-10%). Thicker amphibolites are locally pillowed. Entirely igneous thrust sheet.

INTERPRETED ORIGIN

Allochthonous island arc assemblage; mafic and felsic tuffs with local mafic flows, volcanic-epiclastic rocks, and hypabyssal granitic plutonic rocks. Volcanic and volcanic-epiclastic rocks deposited subaqueously in the Promised Land island arc.

Underlain by the Atlanta thrust sheet

Table 3g. Summary of the Sandy Springs thrust sheet.

Overlain by the Paulding thrust sheet

STRUCTURAL UNITS	STRATIGRAPHIC OR (AND) TECTONOSTRATIGRAPHIC UNITS	GENERAL CHARACTERISTICS
Sandy Springs thrust sheet	Sandy Springs Group: Powers Ferry Formation, Chattahoochee Palisades Quartzite, Factory Shoals Formation, Canton Schist, and parts of the Heard, Mad Indian, Jacksons Gap, Hatchet Creek, and Wedowee Groups of Bentley and Neathery (1970).	Biotite schists, hornblende-plagioclase amphibolites, and biotite-plagioclase gneisses, overlain by clean and micaceous quartzite, overlain by aluminous and garnetiferous schists with quartzite and metagraywacke and lesser amounts of amphibolite.

INTERPRETED ORIGIN

Allochthonous rift-basin fill assemblage from Sandy Springs microcontinent; rift-basin assemblage mixed with volcanic material from Promised Land island arc.

Underlain by the Promised Land thrust sheet

Table 3h. Summary of the Paulding thrust sheet.

Overlain by the West Point thrust sheet

STRUCTURAL UNITS	STRATIGRAPHIC OR (AND) TECTONOSTRATIGRAPHIC UNITS	GENERAL CHARACTERISTICS
Paulding thrust sheet	Paulding Volcanic-Plutonic Complex	Essentially a wholly igneous thrust sheet composed of light-green-weathering, epidote-rich, generally chloritic, green or blue-green hornblende- or (and) actinolite-plagioclase amphibolites (50-60%), intercalated with light-gray to nearly white, amphibole-bearing felsites (20-30%). Dikes and sills of K-feldspar-poor and K-feldspar-rich granitic rocks (15-20%) are ubiquitous, and pods of epidosite are common.

INTERPRETED ORIGIN

Allochthonous island arc assemblage; mafic, intermediate, and felsic tuffs, extensively intruded by granitic rocks; formed in the Paulding island arc.

Underlain by the Sandy Springs thrust sheet

Table 3i. Summary of the West Point thrust sheet.

Overlain by the Ropes Creek thrust sheet

STRUCTURAL UNITS	STRATIGRAPHIC OR (AND) TECTONOSTRATIGRAPHIC UNITS	GENERAL CHARACTERISTICS
West Point thrust sheet.	West Point melange	Mafic melange. Matrix generally composed of highly sheared talcose and (or) chloritic material or of highly deformed scaly schist, both containing clasts of various sizes and degrees of roundness of a wide variety of mafic and ultramafic rocks and locally of eclogite.

INTERPRETED ORIGIN

Allochthonous subduction melange; part of a subduction melange formed at the oceanward edge of the oceanic Paulding island arc.

Underlain by the Paulding thrust sheet

Table 3j. Summary of the Ropes Creek thrust sheet.

Overlain by the Soapstone Ridge thrust sheet

STRUCTURAL UNITS	STRATIGRAPHIC OR (AND) TECTONOSTRATIGRAPHIC UNITS	GENERAL CHARACTERISTICS
Ropes Creek thrust sheet.	Ropes Creek Metabasalt and its Cedar Lake Formation Member. Informal: Ketchepedrakee, Mitchell Dam, and Beaverdam amphibolites, and Hillabee greenstone.	Generally finely layered, dark-green, dark-red-weathering, hornblende-plagioclase amphibolites (metabasalts), commonly garnet-, sphene-, and pyrite-bearing, locally chloritic and epidotic, locally with actinolite. Metabasalts are locally massive and pillowed. Contains massive volcanogenic sulfide deposits associated with volcanogenic iron formations, manganiferous schists, and thin layers of tourmalinite in linear siliceous and (or) aluminous, magnetite-, garnet-, and pyrite-rich alteration zones. Associated granitic plutonic rocks are K-feldspar-poor. Essentially a mafic igneous sheet, devoid of clastic metasedimentary rocks.

INTERPRETED ORIGIN

Allochthogenetic ocean ridge assemblage and seafloor basalts (OPHIOLITE); basalts and basaltic tuffs formed at or very near the mid-Iapetus ridge, mixed with lesser amounts of pelagic sediments, and locally containing volcanogenic sulfides and volcanogenic chemical sediments.

Underlain by West Point thrust sheet

Table 3k. Summary of the Soapstone Ridge thrust sheet.

Top of the Georgiabama thrust stack - Overlain by the Little River thrust stack

STRUCTURAL UNITS	STRATIGRAPHIC OR (AND) TECTONOSTRATIGRAPHIC UNITS	GENERAL CHARACTERISTICS
Soapstone Ridge thrust sheet.	Soapstone Ridge Complex, Laurel Creek Complex of Hatcher and others (1984), Goodwater and Boyds Creek Complexes (Bentley and Neathery, 1970; Reynolds, 1972; Neathery, 1975), Doss Mountain amphibolite and Slaughters Gabbro (Neilson, 1983).	Mafic-ultramafic complexes commonly with thin basal units of dunite or (and) peridotite that has been sheared and altered to serpentinite and talc-chlorite schist, overlain either by mixed units of altered ultramafic rock and uralitized and chloritized metagabbroic rocks, or by uralitized and chloritized metapyroxenites, or by both assemblages. Ultramafic rocks commonly rich in nickel and chrome.

INTERPRETED ORIGIN

Allochthonous (obducted) Iapetus oceanic crust and mantle (OPHIOLITE); incomplete, disrupted ophiolite complexes.

Underlain by the Ropes Creek thrust sheet

LITTLE RIVER THRUST STACK

Structurally above the Georgiabama thrust stack is the Little River thrust stack, composed (in ascending order) of the Macon melange (thrust sheet), Little River allochthon, and the Northern Florida platform sequence (figs. 2 and 46). These sheets (which are all allochthogenetic to the North American craton) were apparently assembled from bottom to top as the "African" continent collided with the North American continent, and were thrust upon the Georgiabama thrust stack. Because of its importance in interpretation of the other two units, the Little River allochthon is described first.

Little River allochthon

Much of the southeasternmost part of the southern Appalachian orogen is underlain by thick sequences of mildly metamorphosed volcanic, volcaniclastic, volcanic-epiclastic, and intrusive rocks traditionally assigned to various "belts," including parts of the "Carolina slate," "Raleigh," "Belair," "Little River," "Kiokee," "Charlotte," and "Uchee" "belts" (Kish and Black, 1982 and references therein). These rocks are all part of the same volcanic arc assemblage as implied by Cook (1983) and Secor and others (1983), and we assign them all to the (probably composite) Little River allochthon (figs. 1, 2, and 46).

Many of the rocks in the Little River allochthon have well-preserved igneous and sedimentary textures, and most have only been metamorphosed to the greenschist facies. Sedimentary features commonly indicate shallow-water or subaerial environments (Bramlette, 1980; Snoke and others, 1980; Green and others, 1982 and references therein). Metavolcanic and metavolcaniclastic rocks are generally more common in the lower parts of the sequences, and epiclastic rocks are more common in the upper parts (Sundelius, 1970; Whitney and others, 1978; Bell and others, 1980; Snoke and others, 1980; Green and others, 1982; Rogers, 1982), indicating that by Middle Cambrian time the arc was dying ("constructive" versus "destructive" phases of Rogers, 1982). The metavolcanic and metavolcaniclastic rocks are bimodal and calcalkaline, with characteristics indicative of a continental-margin arc environment (Rogers, 1982 and references therein).

Radiometric ages from metavolcanic rocks in the allochthon (see Kish and Black, 1982 for a summary) indicate latest Precambrian through Cambrian ages, and latest Precambrian and Cambrian fossils have been found at several localities (Gibson and others, 1984; Secor and others, 1983 and references therein). One of the latest finds of numerous trilobites near the top of the thick section in western South Carolina shows that these fossils are restricted to the upper two-thirds of the Middle Cambrian and are characteristic of the Atlantic faunal province (Secor and others, 1983). Thus, the sequences in the Little River allochthon probably span from latest Precambrian through Middle Cambrian, and were deposited in a volcanic arc (Little River arc) at the oceanward edge of the "African" continent. The sequences are probably slightly older in the northeastern parts of the allochthon, and slightly younger in the southwestern parts (Green and others, 1982; Secor and others, 1983; D.T. Secor, Jr., oral commun., 1982). The lack of radiometric ages younger than Cambrian throughout the allochthon, the fact that Middle Cambrian trilobites occur near the top of what is probably one of the youngest of the sequences, and the suggestion that some of the younger radiometric ages are probably minimum ages (Kish and Black, 1982) implies that volcanism in the Little River arc ceased before or during the Late Cambrian.

Macon melange

Structurally beneath the Little River allochthon is the Macon melange (Higgins and others, 1984), more than 100 km wide at its greatest preserved width, and more than 500 km long (fig. 46). The Macon melange is comparable in size and complexity

with the Franciscan melange of coastal California and Oregon (Cloos, 1982 and references therein), but smaller than most active and fossil melanges in the Indonesian region (Hamilton, 1979 and references therein). Nevertheless, it is the largest melange known in the Appalachians, and one of the largest Paleozoic melanges known in the world. Rocks of the Macon melange have previously been assigned to various "belts," including parts of the "Charlotte," "Kiokee," "Uchee," "Raleigh," "Kings Mountain," "Pine Mountain," "Inner Piedmont," "Lowndesville," and "Carolina slate" "belts."

The Macon melange is a tectonic, sedimentary, and metamorphic chaos, where well-rounded to angular clasts of contrasting metamorphic grades, vastly different sizes, different igneous parentages, drastically different sedimentary facies, and different degrees of deformation "float" in highly imbricated and tectonized matrices (for example note the confusing picture given by Glover and others, 1983, p. 231-233). The Macon melange locally has characteristics of Cowan's (1985) "type I and type II" melanges, but most commonly would fit into Cowan's "type III" melange. The melange is divisible into three tectonostratigraphic slices that probably reflect different structural regimes (see Hamilton, 1979; and Moore and others, 1985) within the accretionary melange wedge: (1) the Potato Creek slice, characterized by an abundance of clastic matrix rocks and the local presence of thin tuffaceous metacherts; (2) the Juliette slice, characterized by an abundance of mafic and ultramafic clasts; and (3) the Po Biddy slice, characterized by metamorphosed manganiferous sediments, metavolcaniclastic rocks, graphitic schists, and locally by metamorphosed thinly bedded pyritiferous limestones, and with a wide variety of mineral deposits. Contacts between the slices are generally thrust faults, but locally they are so imbricated that they give the appearance of being broadly gradational.

Potato Creek and Juliette slices

The Potato Creek and Juliette facies of the Macon melange have previously been assigned to parts of the "Charlotte," "Uchee," "Pine Mountain," "Kiokee," "Inner Piedmont," and "Carolina slate" "belts." The matrix of the Potato Creek and Juliette slices of the Macon melange is an imbricate complex of (most to least common) intershingled massive (but broken), coarse-grained, quartzose, feldspathic, semischistose and schistose, generally amphibole-bearing, biotite metagraywackes, semischistose pebbly mudstones, semischists with thin, broken metagraywacke beds, and thin tuffaceous metacherts interbedded with scaly schist composed of manganiferous mica, plagioclase, and amphiboles (fig. 47). Structural discontinuities and pervasive anastomosing shear-planes abound in the matrix at all scales (fig. 48). The matrix of the Potato Creek and Juliette slices is essentially the same.

All types of matrices in the Potato Creek and Juliette slices contain exotic clasts of metagabbroic rocks, amphibolites, metavolcanic and metavolcanic-epiclastic rocks identical with rocks of the overlying Little River allochthon, folded and unfolded tuffaceous metachert, fine-grained unmetamorphosed-appearing diabase, medium-grained garnet diabases, altered and unaltered or barely altered ultramafic rocks, contorted biotite gneisses, and high-grade schists (figs. 47 and 49). Structures within the clasts do not pass into the matrix, which appears to have "shear-flowed" around the clasts. The clasts range in size from small fragments seen in thin sections to slabs kilometers long and kilometers wide, and in shape from well-rounded to angular.

Some of the larger exotic mafic slabs and aggregates of mafic blocks and slabs in the Macon melange have been considered intrusions. These large clasts are concentrated in, but not confined to, the Juliette slice. Locally, mafic clasts are so abundant in the Juliette slice that the matrix is nearly obscured, and aggregates of clasts have been considered to be larger intrusive bodies. The

Gladesville, Juliette, Berry Creek, and Holly Grove bodies (Matthews, 1967; Prather, 1971; Carpenter, 1971; Hatcher and others, 1984) in the Juliette slice in central Georgia (fig. 50) and the string of mafic and ultramafic bodies in the Pollards Corner area in eastern Georgia (McLemore, 1965; Crawford, 1968a, 1968c; fig. 1) are examples of large slabs and aggregates of slabs and blocks that have been considered intrusions; Hatcher and others (1984, p. 491, 498) opted for some unspecified type of "tectonic emplacement" for the bodies in central Georgia.

The mafic bodies in central Georgia have been called "norites" (Matthews, 1967; Prather and Radcliffe, 1970; Prather, 1971; Carpenter and Prather, 1971). However, our mapping indicates that fine-grained metadiabase makes up 80-90 percent of the Gladesville body, and that the remaining 10-20 percent is mostly medium-grained metagabbro and amphibolite, with lesser amounts of coarse-grained metapyroxenite.

The body that has been called the "Gladesville norite" (Matthews, 1967; Radcliffe and Prather, 1970; Prather, 1971; Carpenter, 1971) is neither a single large body, nor a norite, but an aggregation of smaller bodies (fig. 51), of various sizes, of metadiabase and metamorphosed olivine gabbro, with lesser amounts of metapyroxenite in the melange matrix. The aggregation is neither as large as, nor the same shape as the body shown in Matthews (1967), Prather (1971), Carpenter (1971), Georgia Geological Survey (1976), and Higgins and others (1984, 1986). Other relatively large bodies that have been called "norites" are mostly gabbros, and are matched at all scales by smaller bodies that can be seen to be blocks or clasts in the melange matrix (fig. 52), providing evidence that the larger bodies are not intrusions, but slabs in the melange.

Our work indicates that the attitude of igneous layering in the "Gladesville body" is not as regular as previous workers have depicted it, and does not support the interpretation (based on structural measurements at 3 outcrops; Matthews, 1967; Carpenter and Hughes, 1970, p. 2) that the Gladesville body is an apophysis on a large stratiform body more than 15 km thick (Carpenter and Prather, 1971) that was intruded after metamorphism and then tilted 60 degrees (Matthews, 1967; Prather, 1971; Carpenter, 1971).

Most previous workers (Matthews, 1967; Prather, 1971; Carpenter, 1971) mapped continuous borders of "hornblende hornfels" and "pyroxene hornfels" around the mafic bodies in the Juliette slice (fig. 50), which they considered thermal aureoles resulting from contact metamorphism of the "country rocks" by intrusion of the mafic bodies. These borders, which aren't nearly as continuous as depicted, but are rather rare, and which are composed <u>entirely</u> of altered mafic rocks, are local alterations of the margins of the mafic slabs and blocks, rather than thermally metamorphosed "country rocks" (quartzo-feldspathic clastic rocks of the melange matrix); the mafic bodies have no thermal aureoles. Ultramafic blocks and slabs in the melange also lack thermal aureoles (for example see McLemore, 1965, p. 27), and must have been emplaced cold. Locally, some of the smaller mafic and ultramafic clasts in the melange have incomplete altered borders around unmetamorphosed-appearing interiors, thus mimicking the discontinuous borders of some the larger slabs and blocks.

Low initial Sr^{87}/Sr^{86} ratios (average 0.7035, but as low as 0.7025) from tholeiitic blocks in the melange in central Georgia (Jones and others, 1974) suggest oceanic derivation, as do ultramafic slabs (now mostly serpentinites and talc-chlorite schists, but originally peridotites and pyroxenites; McLemore, 1965; Whitney and Stormer, 1980, p. 122-123) in the melange. The ultramafic slabs contain chromite, magnetite, and sulfide minerals, and have trace amounts of platinum and nickel (Worthington, 1964; McLemore, 1965). Centimeter-scale disrupted igneous layering is locally present in some of the mafic slabs and blocks (fig. 53), and cumulate textures have been described by Matthews (1967) and Prather (1971).

Wilson's (1981) geophysical study of the "Mecklenburg-Weddington" gabbro complex in the Juliette slice south of Charlotte, North Carolina, indicates that the gabbroic bodies have sharp contacts based on magnetic and radioactivity surveys. His gravity models (1981, p. 35-36) indicate "lopolith-like" bodies only 3.5 to 4.5 km thick and a "sill-like" body about 2 km thick. Lawrence's (1985, and oral commun., 1985) detailed gravity survey of a large area in the melange in west-central South Carolina indicates that the mafic "plutons" there can be no more than a few kilometers thick, and some are as little as 1.6 kilometer thick. The shapes and thicknesses are more compatible with large slabs in a melange than with large intrusive plutons, and certainly more compatible with slabs than with a mafic batholith as much as 7 km thick.

McSween and others (1984, p. 452-455) have recently summarized data indicating that many of the gabbroic rocks in the Juliette slice were "emplaced" between 520 and 580 m.y. ago, and probably metamorphosed about 400 m.y. ago, but that some were intruded about 400 m.y. ago. The "emplacement" ages match well with our interpretation of the age of activity of the melange wedge and the Little River arc, and we suggest that the metamorphic ages represent the time of collision and of thrusting of the arc upon the melange and of the melange upon the Georgiabama thrust stack.

In addition to the clasts of mafic and mafic-ultramafic rocks in the melange, there also appear to be intrusive gabbroic bodies in the melange in the Carolinas (McSween and others, 1984, and references therein). These younger mafic bodies are locally associated with syenite, and where the syenites have been dated they give radiometric ages of about 400 m.y. (Fullagar, 1971, 1981, 1983; Butler and Fullagar, 1978; Eric Hund and A.K. Sinha, oral commun., 1985), matching the inferred age of the metamorphism. We have not separated the ~400 m.y. intrusive bodies from the older clasts through most of the melange outcrop belt in the Carolinas.

In our opinion, the evidence is compelling that many of the mafic and mafic-ultramafic bodies, and all of the ultramafic bodies, in the Macon melange are clasts of Iapetus Ocean crust and mantle (disrupted ophiolite) offscraped and incorporated into the melange; the tuffaceous ribbon metacherts and manganiferous scaly schists were probably pelagic sediments deposited on the Iapetus Ocean floor, and offscraped (see Moore and others, 1981; Moore and Biju-Duval, 1984; Moore and others, 1985; and Cowan, 1985) and incorporated into the melange along with semischist and semischistose metagraywacke trench sediments. The metamorphosed pebbly mudstones and associated quartzose metagraywackes probably represent continental clastic sediments deposited on top of the melange wedge and imbricated into it in the manner described by Hamilton (1979, p. 28-31). The Juliette slice is probably a tectonostratigraphic horizon (see Moore and others, 1985; Cowan, 1985, p.461, fig. 10) where concentrations of disrupted Iapetus ophiolite were imbricated into the melange wedge.

Po Biddy slice

Rocks of the Po Biddy slice have previously been assigned to parts of the "Pine Mountain," "Uchee," "Lowndesville," "Kings Mountain," and "Raleigh" "belts," and to the "Avalon terrane." We interpret the Falls Lake melange in the Raleigh, North Carolina area (Horton and others, 1985) to belong to the Macon melange. We have interpreted these rocks as belonging to the Po Biddy slice of the Macon melange because they contain significant units of graphitic schist and metavolcanic rocks (also see Parker, 1979).

The matrix of the Po Biddy slice is an imbricate complex of mafic, intermediate, and (locally graphitic) siliceous and felsic metavolcaniclastic rocks, graphitic schists, and manganiferous schists. Large clasts in this slice are mostly

elongate (some are continuous for tens of kilometers, but most are not), as shown by the mapping of Horton (1981a), Murphy and Butler (1981), Butler (1981), Posey (1981), and our own work, and consist of rocks identical with the matrix, as well as manganiferous quartzites, aluminous quartzites, metamorphosed thinly bedded and laminated, chloritic and pyritiferous limestones (fig. 54), calc-silicate rocks, metaconglomerates, and various metagabbroic and serpentinized ultramafic rocks. In many places the Po Biddy slice has deposits of barite, iron, sulfides, gold, lead, silver, and manganese (Parker, 1979; Sharp and Hornig, 1981; Posey, 1981 and references therein). Tin-spodumene pegmatites occur locally along the northwest edge of the slice (White, 1981 and references therein). The limestones, graphitic schists, and manganiferous schists were probably pelagic sediments, the metalliferous deposits were probably mostly oceanic volcanogenic exhalative deposits (also see Sharp and Hornig, 1981, and Posey, 1981), the manganiferous quartzites were probably volcanogenic chemical sediments (cherts), and the aluminous quartzites were probably volcanogenic alteration zone deposits.

Northern Florida platform sequence

Much of the southeastern part of the Little River thrust stack is covered by Mesozoic and Cenozoic deposits of the Atlantic Coastal Plain. The terrane beneath the Coastal Plain deposits is known mainly from geophysical data and oil-well test holes, and its geology has been recently synthesized by Chowns and Williams (1983). Their study showed that much of the subcrop of northern Florida and southeast Georgia consists of very mildly metamorphosed, mostly felsic, volcanic, volcaniclastic, volcanic-epiclastic, and intrusive rocks of probable latest Precambrian -Cambrian age, which we interpret as belonging to the Little River allochthon. Overlying this part of the Little River allochthon in northern Florida is a sequence of fossiliferous Ordovician to Devonian clastic sedimentary rocks, which Chowns and Williams (1983) referred to as the Northern Florida platform sequence. Fossils in these rocks belong to the Atlantic faunal province (Applin, 1951; Bridge and Berdan, 1952; Pojeta and others, 1976; Chowns and Williams, 1983, and references therein). Present data are insufficient to tell if the Northern Florida platform sequence is thrust upon the Little River allochthon or not; the work of Arden (1974a, 1974b) suggests that it is thrust upon the allochthon. In an earlier paper (Higgins and others, 1984) we suggested that the Northern Florida sequence might be a back-arc basin sequence deposited on the side of the Little River arc nearest the "African" continent. That interpretation is incorrect, because volcanic material is unknown in the sequence and the lithologies in the sequence (shales, siltstones, crossbedded sandstones, and quartz arenites) suggest a shelf environment (Chowns and Williams, 1983, p. L9-L10). Perhaps these rocks were deposited on the African continent (as suggested by Chowns and Williams, 1983) and thrust into their present position at the top of the Little River allochthon when that continent collided with the accreted allochthon.

Structure

The Macon melange structurally underlies the Little River allochthon. Southeast of its main outcrop belt, the melange crops out in antiforms that are essentially windows through the overlying allochthon; these antiforms and accompanying synforms verge northwest. Many of the folds in the melange are chaotic. Isoclinal folds in pebbly mudstones show no axial planar schistosity; both round and angular quartz pebbles and rock fragments are unflattened (figs. 47 and 49), and deformational features consist of a cleavage that generally crosses the folds at an angle, anastomosing semischistosity planes that "flow" around the clasts, and numerous small thrust faults that are common even at outcrop scale. These minor folds are almost certainly the result of soft-sediment deformation caused by gravitational

movement at the top and shear at the base of the wedge (see Hamilton, 1979). Other minor folds appear to be "metamorphic-tectonic," and the majority of these verge northwest, suggesting that they formed during North American cratonward transport of the Macon thrust sheet.

In the Carolinas, the thrust fault at the base of the Macon melange (fig. 55) is marked by a narrow imbricate shear zone that has been called the Kings Mountain shear zone to the north (Horton, 1981b; Horton and Butler, 1981), and the Lowndesville shear zone to the south (Griffin, 1970, 1981; Nelson, 1981). Near the Georgia-South Carolina State Line, the shear zone diverges from the fault at the base of the melange and continues to the southwest just southeast of the Elberton batholith, where it has been called the Middleton-Lowndesville shear zone (Rozen, 1978, 1981; Davis, 1980; Nelson, 1981). The fault at the base of the melange continues on a more westerly course to intersect the northeastern end of the Elberton batholith, which has intruded it. Previous workers have indicated (based on aeromagnetic data) that the shear zone trends southwest to join the Towaliga fault in central Georgia. Our mapping shows that this is not the case, however; the Middleton-Lowndesville shear zone either dies out within, or becomes lost in, the tectonic chaos of the Juliette slice of the Macon melange southwest of Greensboro, Georgia (figs. 1 and 46). The Towaliga fault dies out within rocks of the Great Smoky Group in the Bill Arp thrust sheet north of Monticello, Georgia (fig. 1). The fault at the base of the Macon melange emerges from the southwest end of the Elberton batholith and trends southwest to locally coincide with what has previously been mapped as the Bartletts Ferry fault. In this course, it is locally coincident with what has been mapped as the Goat Rock fault. Thin mylonite zones are present along the "Bartletts Ferry" and "Goat Rock" "faults," and in rocks in between the faults, but most of the rocks that Bentley and Neathery (1970) and Higgins (1971) called blastomylonites in these areas are metamorphosed pebbly mudstones like some of the rocks in figure 47; they belong to the Macon melange. Because the fault at the base of the Macon melange does not everywhere coincide with the named shear zones (Kings Mountain, Middleton-Lowndesville, Lowndesville), nor with the "belt" boundaries, we call this fault the Macon melange thrust fault.

The age of the Elberton Granite places constraints upon the time of final emplacement of the Macon melange and Little River allochthon (figs. 1 and 46), because the Elberton has intruded both units and the Macon melange thrust fault. However, in our opinion, the age of the Elberton is not well established. Zircons from the Elberton Granite yield discordant ages on a concordia plot that have an upper intercept of 320±20 m.y. (Ross and Bickford, 1980), whereas rubidium-strontium analyses form two isochrons, one at 376±45 m.y., and one at 350±11 m.y. (Whitney and Hess, 1980). Whitney and Hess (1980) suggested that 320±20 m.y. was the age of magmatic crystallization of the Elberton Granite. But what do the rubidium-strontium ages mean and why are they older than the zircon ages?

Modoc zone

Howell and Pirkle (1976, p. 16) gave the name "Modock fault zone" to a 4-5 kilometer wide zone of button schists and mylonites which they considered to mark the boundary between the "Carolina slate belt" and the "Kiokee belt"; Hatcher and others (1977) shortened the name to "Modoc fault," and suggested that it extends (based on aeromagnetic data) through North Carolina as part of their "Eastern Piedmont fault system." Subsequent workers have considered the fault to be the boundary between the "Carolina slate" and "Kiokee" "belts" (Secor and Stoke, 1978; Williams, 1978; Snoke and others, 1980; Maher and others, 1981; Secor and others, 1983; Price and Hatcher, 1983). Hatcher and Odom (1980, p. 324) showed the Modoc as a thrust with teeth on the northwestern side which they stated indicates "(direction of dip)" of "probable or known thrust or reverse faults.", and more

recently, McConnell and Abrams (1984, p. 9) and Abrams and McConnell (1984, p. 1522) following Hatcher and Odom (1980) showed the Modoc as a fault with teeth on the northwest side but did not provide an explanation. Hatcher and Odom (1980), McConnell and Abrams (1984), and Abrams and McConnell (1984) show the Modoc fault cutting Coastal Plain sediments in east-central Georgia.

Our mapping (fig. 1) shows that the Modoc zone is a zone of extreme flattening and mylonitization (also see Hatcher and others, 1977) less than about 300 meters wide, that it is located well within metavolcanic rocks of the Little River allochthon and does not form any major tectonic or lithologic boundary - it is not the fault (Little River thrust fault) that separates the Little River allochthon from the underlying Macon melange. It does not extend far enough to the southwest to intersect Coastal Plain sediments and it definitely does not cut those sediments.

Metamorphism

A major problem in the study of melanges is that the metamorphic grade of clasts in a melange is commonly different from that of the matrix (Hamilton, 1979; Drake and Morgan, 1981; Cloos, 1982, and references therein). Grade of metamorphism is generally determined from the highest grade mineral assemblages in a given area, and metamorphic isograds are determined by the first occurrence of index minerals. The metamorphic grade of clasts in a melange may be mistaken as indicating the ambient metamorphic grade of the melange.

The Potato Creek and Juliette slices of the Macon melange, which coincide in part with the "Charlotte," "Kiokee," and "Uchee" "belts," have generally been considered to be at high metamorphic grade. These slices do contain clasts of sillimanite grade rocks, but the highest grade minerals thus far observed in the matrices are biotite, garnet, and amphiboles. Hence, these matrices may not be any higher in grade than the supposedly low-grade "Kings Mountain belt" which is mostly the Po Biddy slice of the Macon melange (see Horton, 1981a; Horton and Butler, 1981; Gregory, 1981), and locally they appear to be at garnet grade.

Paleogeographic reconstruction

The structural position of the Macon melange beneath and also northwest of the Little River allochthon (figs. 1 and 61), the presence of clasts of allochthon rocks in the melange, the northwest vergence of major and some minor folds in the melange, and the presence of Atlantic faunal province trilobites in the allochthon rocks indicate that the melange and the allochthon were thrust from the southeast (present direction), and that the subduction zone dipped toward the "African" continent (fig. 61). The cessation of volcanism in the Little River arc, apparently in the Late Cambrian, was probably caused by the Macon melange and the arc ("African" plate) overriding the mid-Iapetus ridge, just as part of western North America overrode the East Pacific Rise in the Miocene. Part of the Iapetus Ocean crust and mantle (welded to the bottom of the stack and metamorphosed and depleated) must have been thrust upon the North American continent along with the overlying Little River thrust stack, because the southern Appalachian gravity gradient coincides closely with the northern border of the melange (Long, 1979) and because Hercynian granitic plutons associated with the Little River stack have low initial Sr^{87}/Sr^{86} ratios and low δO^{18} ratios, which decrease to the southeast (Sinha and Zietz, 1982, and references therein).

Summary Table

Summaries of some of the salient characteristics of the thrust sheets in the Little River thrust stack are given in table 4.

Table 4. Summaries of thrust sheets in the Little River thrust stack.

Table 4a. Summary of the Macon melange thrust sheet.

Overlain by the Little River allochthon

STRUCTURAL UNITS	STRATAGRAPHIC OR (AND) TECTONOSTRATIGRAPHIC UNITS	GENERAL CHARACTERISTICS
Potato Creek, Juliette, and Po Biddy slices.	Uchee Complex (Bentley and Neathery, 1970), and parts of the "Charlotte," "Kiokee," "Uchee," "Inner Piedmont," "Kings Mountain," "Lowndesville," "Raleigh," "Pine Mountain," and "Carolina slate" "belts."	Po Biddy slice: matrix is an imbricate complex of mafic, intermediate, and (locally graphitic) felsic metavolcaniclastic rocks, graphitic schists, and manganiferous schists containing elongate clasts of rocks identical to the matrix, manganiferous quartzites, aluminous quartzites, metamorphosed thinly bedded and laminated chloritic and pyritiferous limestones, calc-silicate rocks, metaconglomerates, and various metagabbroic and serpentinized ultramafic rocks; Juliette slice: matrix is an imbricate complex of (most to least common) interhingled massive (but broken), coarse-grained, quartzose, feldspathic, semischistose and schistose, generally amphibole-bearing, biotite-plagioclase metagraywackes, semischistose pebbly mudstones, semischists with thin broken metagraywacke beds, and thin tuffaceous metacherts interbedded with scaly schist composed of manganiferous mica, plagioclase, and amphiboles; Structural discontinuities and pervasive anastomosing shear-planes abound in the matrix at all scales; contains exotic clasts of metagabbroic rocks, amphibolites, metavolcanic and metavolcanic-epiclastic rocks, folded and unfolded tuffaceous metachert, fine-grained unmetamorphosed-appearing diabase, medium-grained garnet diabases, altered and unaltered or barely altered ultramafic rocks, contorted biotite gneisses, and high-grade schists; clasts range in size from tiny fragments to slabs tens of kilometers long and in shape from well-rounded to angular; slice is literally crowded with clasts of mafic and ultramafic rocks; Potato Creek slice: identical with the Juliette slice, but with less numerous clasts of mafic and ultramafic rocks.

INTERPRETED ORIGIN

Sliced-off remnants of different parts of a subduction melange wedge; Po Biddy - near toe of wedge where pelagic sediments, Iapetus Ocean crust, and sediments moving down the top of the wedge are imbricated together; Juliette - near bottom of wedge where more Iapetus Ocean crust was off-scraped and imbricated into the wedge; Potato Creek - near to of wedge where more sediments moving down the top of the wedge were imbricated into the wedge.

Table 4b. Summary of the Little River allochthon.

Overlain by the Northern Florida platform sequence

STRUCTURAL UNITS	STRATIGRAPHIC OR (AND) TECTONOSTRATIGRAPHIC UNITS	GENERAL CHARACTERISTICS
Little River allochthon	"Little River series" of Crickmay (1952), Lincolnton Metadacite (Whitney and others, 1978), and parts of the "Little River," "Carolina slate," "Belair," "Kiokee," "Charlotte," "Raleigh," and "Uchee" "belts."	Felsic (~70-80%) and mafic (~20-30%) metavolcanic, metavolcaniclastic, and metavolcanic-epiclastic rocks, including metasubvolcanic rocks and hypabyssal plutonic rocks. Metavolcanic rocks are more common in lower parts of sequence and metavolcanic-epiclastic rocks more common in upper parts. Atlantic faunal province trilobites of late Middle Cambrian age found in upper uppermost part of sequence in western South Carolina.

INTERPRETED ORIGIN

Continental-margin calcalkaline arc deposits formed in arc at edge of "African" microcontinent.

Underlain by the Macon melange thrust sheet

Table 4c. Summary of the Northern Florida platform sequence.

Top of the Little River thrust stack - No higher rocks known in the southernmost Appalachians

STRUCTURAL UNITS	STRATIGRAPHIC OR (AND) TECTONOSTRATIGRAPHIC UNITS	GENERAL CHARACTERISTICS
Northern Florida platform sequence	Unnamed Ordovician through Devonian sedimentary rocks beneath the Coastal Plain.	Unmetamorphosed, fossiliferous Lower Ordovician through Middle Devonian gray, red, and black siltstones, sandstones (locally crossbedded), quartz arenites, and micaceous shales. Clastic sequence apparently without volcanic components.

INTERPRETED ORIGIN

Platform (shelf) sequence deposited on African craton.

Underlain by the Little River allochthon

ROME-KINGSTON THRUST STACK

Much of the Valley and Ridge province in northwest Georgia and northeast Alabama (fig. 1) is underlain by Paleozoic sedimentary rocks in three major thrust sheets (Butts, 1926; Allen and Lester, 1957; Cressler, 1963, 1964a, 1964b, 1970, 1974; Chowns and McKinney, 1980; Thomas and Neathery, 1980; Chowns and Carter, 1983), which we call (following Chowns and McKinney, 1980, and Chowns and Carter, 1983) the Kingston, Clinchport, and Rome thrust sheets (table 5). These sheets make up the Rome-Kingston thrust stack. Each thrust sheet is composite because each is cut into slices by other thrust faults, and each contains some of the rock units found in the others. However, each sheet contains sedimentary facies not found in the other sheets, each appears to represent a slightly different paleotectonic environment, and each has had a slightly different deformational history from the others. Underlying the Rome-Kingston thrust stack is a parautochthonous/autochthonous terrane, which we call the Chickamauga terrane.

Chickamauga terrane

The Chickamauga terrane, structurally underlying the Rome-Kingston thrust stack, is a parautochthonous/autochthonous terrane that is transitional (structurally and in paleodepositional environments) between the Valley and Ridge province and the "more stable" craton of the Cumberland (or Allegheny) Plateau province. Rocks in the Chickamauga terrane in Georgia and Alabama range in age from Early Cambrian through Early Pennsylvanian (Butts, 1926; Allen and Lester, 1957; Cressler, 1963, 1964a, 1964b, 1970; Thomas and Cramer, 1979; Thomas, 1979; Smith, 1979; Chowns and McKinney, 1980; Thomas and Neathery, 1980; Chowns and Carter, 1983; Rich, 1983; Crawford, 1983; table 5). The lower part of the section is part of the Appalachian Cambrian-Ordovician carbonate shelf sequence (Rodgers, 1953, 1968, 1982; Cressler, 1970, 1974; Palmer, 1971; Thomas and Neathery, 1980; Chowns and McKinney, 1980). The carbonate shelf sequence in the Chickamauga terrane consists of the Lower Cambrian Rome Formation (the Shady Dolomite and rocks of the Chilhowee Group are apparently missing - Kidd and Neathery, 1976; Thomas and Neathery, 1980, p. 469), the Middle and Upper Cambrian Conasauga Formation, the Upper Cambrian and Lower Ordovician Knox Group, consisting of the Upper Cambrian Copper Ridge and Chepultepec Dolomites and the Longview Limestone, and Lower Ordovician Newala Limestone, and the Middle Ordovician Lenoir Limestone (Butts, 1926; Cressler, 1970, 1974; Cressler and others, 1979; Thomas and Neathery, 1980; Chowns and McKinney, 1980; Chowns and Carter, 1983). Abundant evidence indicates that these rocks were deposited in shallow, warm water on the Cambrian-Ordovician carbonate shelf, and that the clastic material within the sequence came from the North American craton (Rodgers, 1953, 1968, 1982; Palmer, 1971; Thomas and Neathery, 1980; Chowns and McKinney, 1980; Read, 1984, 1985).

In the Chickamauga terrane, Lower Ordovician Knox Group rocks of the carbonate shelf sequence are overlain with marked disconformity by Middle Ordovician rocks of the Chickamauga Supergroup in Georgia (Milici and Smith, 1969; Chowns and McKinney, 1980; Chowns and Carter, 1983), and the Chickamauga Group in Alabama (Drahovzal and Neathery, 1971; Chowns and McKinney, 1980; Chowns and Carter, 1983). The disconformity locally has relief of as much as 13 meters (Drahovzal and Neathery, 1971b, p. 187; Chowns and McKinney, 1980), and depressions in the karstic surface are filled with basal Chickamauga conglomeratic beds of the Pond Spring Formation in Georgia (Jackson, 1951; Munyon, 1951; Milici and Smith, 1969; Chowns and McKinney, 1980) and the Attalla Conglomerate Member of the Stones River Formation in Alabama (Butts, 1910; Drahovzal and Neathery, 1971). These basal beds are overlain by tidal flat and lagoonal deposits composed of mottled grayish-red mudstone and silty limestone interbedded with micritic limestones (Pond Spring-Stones River), which are in turn overlain by Chickamauga Supergroup (Group in Alabama) shallow-water

Table 5a. Stratigraphic units in the Chickamauga terrane and Rome-Kingston thrust stack in Georgia (modified from Cressler, 1963, 1964a, 1964b, 1970, 1974; Cressler and others, 1979; Chowns and McKinney, 1980; Chowns and Carter, 1983; Rich, 1983; Crawford, 1983; Carter and others, 1983).

		Chickamauga terrane	Kingston thrust sheet	Clinchport thrust sheet	Rome thrust sheet
CARBONIFEROUS	PENN.	Gizzard Group	Gizzard Group	Gizzard Group	
		Pennington Formation	Pennington Formation	Pennington Formation	
		Bangor Limestone	Bangor Limestone	Bangor Limestone	
	MISS.	Monteagle Limestone	Floyd Shale	Floyd Shale	Floyd Shale
		Tuscumbia Limestone			
		Fort Payne Chert	Fort Payne Chert	Fort Payne Chert	Fort Payne Chert
		--unconformity--	--unconformity--	--unconformity--	--unconformity--
		Maury Shale	Maury Shale	Maury Shale	
	DEVONIAN	Chattanooga Shale	Chattanooga Shale	Chattanooga Shale	
		--unconformity--	--unconformity--	--unconformity--	
			Armuchee Chert	Armuchee Chert	Frog Mountain Sandstone
			--unconformity--	--unconformity--	--unconformity--
	SILURIAN	Red Mountain Formation	Red Mountain Formation	Red Mountain Formation	
		--unconformity--	--unconformity--	--unconformity--	
ORDOVICIAN	Chickamauga Supergroup / Nashville Group	Sequatchie Formation			
		Catheys Formation	Sequatchie Formation	Sequatchie Formation	
		Cannon Limestone	(northwestern facies)	(southeastern facies)	
		Hermitage Formation			
		Carters Limestone	Colvin Mountain Sandstone	Colvin Mountain Sandstone	Tellico-Chota Formations
	Stones River Group / Chickamauga Supergroup		(northwestern facies)	(southeastern facies)	Rockmart Slate, Athens Shale
		Lebanon Limestone		--unconformity--	--unconformity--
		Ridley Limestone			
		Murfreesboro Limestone	Greensport Formation	Greensport Formation	
		Pond Spring Formation	(northwestern facies)	(southeastern facies	Lenoir Limestone
		--unconformity--	--unconformity--	--unconformity--	--unconformity--
	Knox Group	Newala Limestone	Newala Limestone	Newala Limestone	Newala Limestone
		Longview Limestone	Longview Limestone	Longview Limestone	Longview Limestone
		Chepultepec Dolomite	Chepultepec Dolomite	Chepultepec Dolomite	Chepultepec Dolomite
		Copper Ridge Dolomite	Copper Ridge Dolomite	Copper Ridge Dolomite	Copper Ridge Dolomite
	Knox Group / Conasauga Group				Maynardville Limestone
					Nolichucky Shale
CAMBRIAN		Conasauga Formation	Conasauga Group	Conasauga Group	Maryville Limestone
					Rogersville Shale
					Honaker Dolomite
		Rome Formation	Rome Formation	Rome Formation	Rome Formation
			--Kingston fault--	--Clinchport fault--	Shady Dolomite
					Chilhowee Group
					--Rome fault--

Table 5b. Stratigraphic units in the Chickamauga terrane and Rome-Kingston thrust stack in Alabama (modified from Butts, 1926; Drahovzal and Neathery, 1971; Thomas and Neathery, 1980; Thomas and McKinney, 1980; Thomas and Carter, 1983).

		Chickamauga terrane	Kingston thrust sheet	Clinchport thrust sheet	Rome thrust sheet
CARBONIFEROUS	PENN.	Pottsville Formation	Pottsville Formation	Pottsville Formation	
		Pennington Formation	Parkwood Formation	Parkwood Formation	
		Bangor Limestone	Bangor Limestone	Bangor Limestone	
	MISS.	Monteagle Limestone	Floyd Formation	Floyd Shale	Floyd Shale
		Hartselle Sandstone			
		Pride Mountain Formation			
		Tuscumbia Limestone			
		Fort Payne Chert	Fort Payne Chert	Fort Payne Chert	Fort Payne Chert
		--unconformity--	--unconformity--	--unconformity--	--unconformity--
		Maury Shale	Maury Shale	Maury Shale	
	DEVONIAN	Chattanooga Shale	Chattanooga Shale	Chattanooga Shale	
		--unconformity--	--unconformity--	--unconformity--	
			Frog Mountain Sandstone	Frog Mountain Sandstone	Frog Mountain Sandstone
			--unconformity--	--unconformity--	Jemison Chert
	SILURIAN	Red Mountain Formation	Red Mountain Formation	Red Mountain Formation	--unconformity--
		--unconformity--	--unconformity--	--unconformity--	
		Sequatchee Formation	Sequatchee Formation (northwestern facies)	Sequatchee Formation (southeastern facies)	Butting Ram Quartzite
ORDOVICIAN	Chickamauga Group	Leipers Limestone			Lay Dam Formation
		Inman Formation			--unconformity--
		Nashville Formation	Colvin Mountain Sandstone (northwestern facies)	Colvin Mountain Sandstone (southeastern facies)	Athens Shale, Rockmart Slate
		Stones River Formation	Greensport Formation (northwestern facies)	Greensport Formation (southeastern facies)	--unconformity--
		Attalla Chert Conglomerate	--unconformity--	--unconformity--	
		--unconformity--			
	Knox Group	Lenoir Limestone	Lenoir Limestone	Lenoir Limestone	Lenoir Limestone
		--unconformity--	--unconformity--	--unconformity--	--unconformity--
		Newala Limestone	Newala Limestone	Newala Limestone	Newala Limestone
		Longview Limestone	Longview Limestone	Longview Limestone	Longview Limestone
		Chepultepec Dolomite	Chepultepec Dolomite	Chepultepec Dolomite	Chepultepec Dolomite
CAMBRIAN		Copper Ridge Dolomite	Copper Ridge Dolomite	Copper Ridge Dolomite	Copper Ridge Dolomite
					Maynardville Limestone
		Conasauga Formation	Conasauga Formation	Conasauga Formation	Nolichucky Shale
					Maryville Limestone
					Rogersville Shale
					Honaker Dolomite
		Rome Formation	Rome Formation	Rome Formation	Rome Formation
			--Kingston fault--	--Clinchport fault--	Shady Dolomite
					Chilhowee Group
					--Helena fault--

carbonate units (Murfreesboro, Ridley, Lebanon, Carters, Hermitage, Cannon, and Catheys Formations in Georgia; Nashville, Inman, and Leipers Formations in Alabama) as much as ~440 meters thick in Georgia but thinning to ~80 meters thick in Alabama (Drahovzal and Neathery, 1971, Chowns and McKinney, 1980; Chowns and Carter, 1983). The carbonate sequence is overlain by the Sequatchie Formation, an alluvial red-bed sequence derived from the southeast (Thompson, 1971; Chowns, 1972; Milici and Wedow, 1977; Chowns and McKinney, 1980; Chowns and Carter, 1983). The alluvial red-bed sequence grades up into coarse-grained hematitic sandstones, conglomeratic sandstones, ironstones, red shales, and siltstones of the Lower Silurian (Llandoverian) Red Mountain Formation, also derived from the southeast (Chowns and McKinney, 1980, and references therein). Rindsberg (1982) and Chowns and Carter (1983) have recently suggested that the coarse-grained sandstones traditionally placed in the Red Mountain Formation in northwest Georgia belong to the underlying Upper Ordovician Sequatchee Formation, and that finer grained marine shales and turbidites of the Red Mountain unconformably overlie these coarser-grained rocks.

In the Chickamauga terrane the Red Mountain Formation is unconformably overlain by thin, but persistent, Upper Devonian and Lower Mississippian shale units (Chattanooga and Maury Shales), which are in turn unconformably overlain by Mississippian shelf carbonates and marine shales, capped by Pennsylvanian clastic rocks (Butts, 1926; Allen and Lester, 1957; Conant and Swanson, 1961; Thomas and Cramer, 1979; Thomas, 1979; Smith, 1979; Chowns and McKinney, 1980; Thomas and Neathery, 1980; Chowns and Carter, 1983; Rich, 1983; Crawford, 1983).

Kingston thrust sheet

The Kingston thrust sheet, the lowest sheet in the Rome-Kingston thrust stack is bounded at its base to the northwest by the Kingston thrust fault, and at its top by the Clinchport thrust fault (Chowns and Carter, 1983 and references therein) at the base of the Clinchport thrust sheet (fig. 1). Rocks in the Kingston thrust sheet range in age from the Early Cambrian Rome Formation through the Early Pennsylvanian Gizzard Group (Butts, 1926; Cressler, 1963, 1964a, 1964b, 1970, 1974; Thomas and Cramer, 1979; Chowns and McKinney, 1980; Rich, 1983; Crawford, 1983; Chowns and Carter, 1983; table 5). The lowest sequence of rocks (up through the Upper Cambrian and Lower Ordovician Knox Group) in the Kingston sheet is the carbonate shelf sequence (see references above). In the Kingston sheet, the Middle Ordovician-Lower Silurian sequence records a northwest-to-southeast facies change (Chowns and Carter, 1983, and references therein). In northwestern outcrops in the sheet this sequence is nearly identical to that in the Chickamauga terrane, whereas to the southeast tongues of redbeds increase within the Chickamauga Supergroup carbonate sequence and gradually thicken at the expense of the carbonate rocks from northwest to southeast. These tongues of clastic rocks have been assigned to the Greensport Formation in Georgia by Chowns and McKinney (1980) and Chowns and Carter (1983). In Alabama the Greensport Formation occurs in what we interpret as the Clinchport sheet in a window through the Rome thrust sheet.

The mixed Middle and Upper Ordovician carbonate-red-bed facies is overlain (probably unconformably) by the Lower Silurian Red Mountain Formation, which is unconformably overlain by the Lower and Middle Devonian Armuchee Chert and its Middle Devonian clastic facies, the Frog Mountain Sandstone (Butts, 1926; Allen and Lester, 1957; Cressler, 1963, 1964a, 1964b, 1970, 1974; Neathery and Thomas, 1980 Chowns and Carter, 1983), thus filling part of the hiatus between the Red Mountain Formation and Chattanooga and Maury Shales in the Chickamauga terrane. The sequence overlying the Armuchee Chert is similar to that in the Chickamauga terrane, except for the fact that more of the Mississippian sequence is comprised of shale at the expense of carbonate rocks.

Clinchport thrust sheet

The Clinchport thrust sheet is bounded at its base by the Clinchport thrust fault and at its top by the Rome thrust fault. In this sheet the Cambrian-Ordovician carbonate shelf sequence is disconformably overlain by a Middle and Upper Ordovician sequence composed predominately of clastic sedimentary rocks; the tongues of redbeds have increased at the expense of Chickamauga Supergroup carbonate rocks to the extent that carbonate rocks are found as tongues in the redbeds only in the northwestern edge of the sheet (Chowns and Carter, 1983, and references therein; table 5). The red-bed sequence reaches its maximum thickness (~700 meters) in the southeastern part of the Clinchport sheet. In this area the sequence is composed of the Greensport Formation, Colvin Mountain Sandstone, and Sequatchie Formation (Drahovzal and Neathery, 1971; Chowns and McKinney, 1980; Chowns and Carter, 1983). The overlying Lower Silurian Red Mountain Formation also reaches its greatest thickness (~400 meters) in the southeastern part of the Clinchport sheet (Cressler, 1970; Dravhovzal and Neathery, 1971a; Chowns and McKinney, 1980). The sequence above the Red Mountain Formation in the Clinchport sheet is essentially the same as in the underlying Kingston sheet.

Rome thrust sheet

The Rome thrust sheet is bounded below by the Rome-Helena thrust fault system (Hayes, 1891; Butts, 1926; Butts and Gildersleeve, 1948; Cressler, 1970, 1974; Thomas and Neathery, 1980; Chowns and McKinney, 1980; Chowns and Carter, 1983)*. Most of the Rome thrust sheet is made up of the Cambrian-Ordovician carbonate shelf sequence, which here includes at its base the Lower Cambrian Shady Dolomite, underlain by rocks of the Chilhowee Group (table 5). The thick Middle-Upper Ordovician redbed sequence is absent in the Rome Sheet, its lower parts taken by the lower Middle Ordovician Lenoir Limestone, and the Middle Ordovician Rockmart Slate and Athens Shale (see below). The Lower Silurian Red Mountain Formation is also absent in the eastern parts of this sheet, and the Middle Ordovician slates and shales are overlain with angular unconformity by the Lower and Middle Devonian Armuchee Chert-Frog Mountain Sandstone sequence. The Armuchee-Frog Mountain sequence is unconformably overlain by the Lower Mississippian Fort Payne Chert and Upper Mississippian Floyd Shale. The Mississippian carbonate sequence is absent in the Rome sheet, and was probably never deposited there, its place being partially taken by the Fort Payne and Floyd.

Rockmart Slate, Athens Shale, Tellico Formation, and Talladega Group

Middle Ordovician shales, slaty shales, and slates crop out discontinuously along the eastern and southeastern edge of the Rome thrust sheet (fig. 1). These rocks are of special interest, because their age and structural and stratigraphic position relative to the craton is approximately the same as similar shales and slates in the complex Taconic allochthon of the northern (western New England) Appalachians (Zen, 1961, 1967, 1968; Ratcliffe, 1975, 1979; Fisher, 1969, 1979; Ratcliffe and Hatch, 1979; Rodgers, 1970; Stanley and Ratcliff, 1980; Rowley and Kidd, 1981, Bosworth and Rowley, 1984).

Rockmart Slate, Athens Shale, and Tellico Formation

The Rockmart Slate (Hayes, 1891) is a relatively thin (~180 meters) sequence of slate and siltstone of Middle Ordovician age (and younger?) that crops out

* The Rome fault and Helena fault are probably the same fault, as implied by Chowns and McKinney (1980) and Chowns and Carter (1983); they are separated by only a few kilometers by the flood plain of the Coosa River near Gadsden, Alabama.

immediately north and northwest of the Emerson thrust fault in the Valley and Ridge province in northwestern Georgia and northeastern Alabama (fig. 1). It rests either in thrust contact or unconformably (or both) upon Valley and Ridge carbonate shelf facies rocks as young as the Deaton Member of the lower Middle Ordovician Lenoir Limestone (Cressler, 1970). The lower part (roughly half) of the Rockmart is a dark-gray to nearly black, calcareous slate containing well-developed folds and cleavages and a rich Middle Ordovician graptolite fauna (Cressler, 1970). The upper part of the Rockmart is composed of siltstone and slate with some feldspathic sandstone and with lenses of spectacular polymictic conglomerate made up of angular to subrounded fragments, chips, pebbles, and cobbles of (in order of abundance) limestone, dolomite, slate, sandstone, chert, and quartzite in a matrix of feldspathic sandstone, sandy slate, graywacke, clay slate, or rarely dolomite or limestone (fig. 55). As Cressler (1970), Chowns and McKinney (1980), and Sibley (1983) recognized, some of the quartzite clasts were metamorphosed prior to deposition. As Cressler (1970, p. 25) recognized, some of the slate clasts in the conglomerates lithically match rocks of the lower part of the Rockmart, some of the sandstone clasts lithically match sandstone beds in the lower part of the upper part of the Rockmart, and some of the carbonate clasts lithically match rocks of the carbonate shelf sequence below the Rockmart. He suggested that the slate and sandstone clasts are reworked Rockmart. Conglomerates like those in the upper sequence of the Rockmart have been described in units (Chota and Tellico Formations) in similar stratigraphic and structural positions as far northeast along strike as Fincastle, Va. (Kellberg and Grant, 1956). No fossils have been found above the lower dark slate sequence in the Rockmart Slate.

Like the lower part of the Rockmart Slate, the Athens Shale, which occupies a similar stratigraphic and structural position in Alabama (Butts, 1926; not shown in fig. 1), is a dark-gray to nearly black, calcareous, strongly cleaved and folded slaty shale containing a rich graptolite fauna of Middle Ordovician age (Butts, 1926; Bergstrom and Drahovzal, 1972; Bergstrom, 1973; Finney, 1978, 1980), that either rests in thrust contact or unconformably (or both) upon carbonate shelf facies rocks as young as the Middle Ordovician Lenoir Limestone. Conglomerates like those in the upper part of the Rockmart Slate have not been reported in the Athens Shale in Alabama.

Another outcrop area of Athens Shale is north of Chatsworth in north Georgia (fig. 1). The basal parts of the Athens there, which rest in sharp contact upon the Newala or Lenoir Limestones, are dark-gray to olive-gray, calcareous clayey and silty shale containing interbedded tan, brown, or olive-gray siltstones and sandstones (Butts and Gildersleve, 1948; Munyon, 1951; Jackson, 1951; Cressler, 1974), unlike the dark slates and shales in the basal parts of the Rockmart Slate and Athens Shale to the southwest in Georgia and Alabama. These northern Georgia rocks also appear to be less deformed and less metamorphosed than their counterparts (or near counterparts) to the southwest. However, they also contain a Middle Ordovician graptolite fauna (Cressler, 1974). In this northern Georgia outcrop belt the Athens Shale is overlain by the Tellico Formation as mapped by Butts and Gildersleeve (1948) or the Chota Formation (Neuman, 1955) as mapped by Salisbury (1961). The Chota (or Tellico?) is composed of cross-bedded sandy limestone, calcareous sandstone, and minor amounts of quartz-free limestone, as well as beds and lenses of polymictic conglomerate identical to that in the upper part of the Rockmart Slate (Munyon, 1951; Jackson, 1951; Kellberg and Grant, 1956; Cressler, 1974). According to Mack (1985) the provenance of sandstones in the Athens Shale and Chota Formation in northern Georgia was K-feldspar rich granitic rocks or high grade metamorphic rocks (Grenville basement) and low grade metapelitic slates and phyllites.

The upper, unfossiliferous part of the Rockmart Slate is probably an entirely different unit (Cressler 1970, and oral commun., August 1984) from the lower graptolitic part. This is suggested by the lithologic differences between the two, by the absence of the upper part in some areas where thick sections of the lower part are present, by the presence of what appear to be clasts of the lower slates in the conglomerates in the upper part, and by the lithologic similarities (especially the polymictic conglomerates) of the upper part with the Chota or (and) Tellico Formations. We suggest (as did Cressler, 1970, p. 30) that the upper part of the Rockmart Slate may represent depositional equivalents of both the Tellico Formation and overlying Chota Formation (as defined by Neuman, 1955) in Tennessee. Because it most resembles the Tellico, we here assign this unit to the Tellico Formation.

The Tellico Formation overlying the Rockmart Slate appears to have been derived from the east (or southeast) rather than from the craton or the carbonate shelf. This is indicated (Cressler, 1970) by the size and angularity of some of the noncarbonate clasts in the conglomerates, by the presence of clasts that were metamorphosed prior to sedimentation, by the fact that grain size in sandstone beds increases from west to east and bedding thickens toward the east, and by the fact that (Cressler, 1970, p. 27):

> "The conglomerate lenses in the southeasternmost outcrops are thickest and have the widest lateral extent. They also contain the coarsest and the least rounded pebbles and cobbles, apparently having been deposited nearest the source area."

Cressler (1970, p. 30) described the distribution of the sequence above the dark slates as follows:

> "The lower, predominately slaty part of the Rockmart, beginning near Cedartown in Polk County, is overlain by an eastward thickening wedge of clastics, composed largely of sandstone, conglomerate, and conglomeratic slate."

Both the Athens Shale in Alabama and the Rockmart Slate in Alabama and Georgia are unconformably overlain by the Lower and Middle Devonian Frog Mountain Sandstone, or by its equivalent chert facies the Armuchee Chert (Butts, 1926; Cressler, 1970; Thomas and Drahovzal, 1973). The Frog Mountain (or its equivalents) is not present in the north Georgia Athens Shale outcrop belt. It may have been overidden by Bill Arp thrust sheet rocks on the Carters Dam fault (fig. 1), but it is far more likely that it was never deposited in northern Georgia (also Cressler, oral commun. 1985), its principal development being to the southwest in western Georgia and Alabama. The Frog Mountain Sandstone-Armuchee Chert is unconformably overlain by the Lower Mississippian (Osagean) Fort Payne Chert (Butts, 1926; Cressler, 1970).

Both Cressler (1970) and Sibley (1983) have shown that the Rockmart Slate was deformed prior to deposition of the Frog Mountain Sandstone. For example, Cressler stated (1970, p. 30):

> "At Etna, where the Rockmart re-enters Polk County from Alabama, it is between 200 and 300 feet thick, but it thins toward the east, diminishing to about 20 feet at Oremont, and it is absent a quarter of a mile southeast of there, apparently having been eroded off an anticline that formed prior to deposition of the Frog Mountain Sandstone of Early and Middle Devonian age."

Sibley (1983, p. 34-37) reported that some of the larger pebbles and cobbles in the conglomerates in the Tellico overlying the Rockmart "have a well-developed cleavage that is sharply divergent from the matrix cleavage and appears to have been present prior to deposition."

The contact between the Rockmart Slate and Athens Shale and the underlying rocks of the carbonate shelf sequence (Lenoir and Newala Limestones) is either an unconformity or a thrust fault, or perhaps locally both. According to Bergstrom and Drahovzal (1972), Bergstrom (1973), and Finney (1980) the base of the Athens Shale in Alabama is diachronous. Graptolite data given by Cressler (1970, p. 26-30) and Bergstrom (1973) suggest that this may also be the case with the lower part of the Rockmart Slate. All available paleontological evidence indicates a striking similarity in age between the dark, graptolitic slaty shales and slates and the youngest underlying shallow-water shelf carbonates. Where the contact between the two drastically different facies is exposed, it is always seen to be knife-sharp (fig. 56). The drastic difference in sedimentary facies between the underlying warm, shallow-water shelf carbonates with their shelly faunas (Cressler, 1970) and warm, shallow-water conodonts (A.G. Harris and J.E. Repetski, written commun., May, 1984), and the overlying deeper-water dark shales with their graptolite faunas (Cressler, 1970; Bergstrom and Drahovzal, 1973; Finney, 1980) is also striking. Moreover, the pelitic rocks appear to be more deformed than the underlying carbonate rocks, and they are clearly more metamorphosed than shales in the Rome and Conasauga Formations in the same structural position only a short distance away. The relations between the Rockmart Slate and Athens Shale and the underlying carbonate shelf sequence rocks suggest to us that the contact between them is at least locally (particularly around Rockmart, Georgia) a thrust fault.

Bergstrom and Drahovzal (1972) and Bergstrom (1973) have shown that the base of the Athens Shale in the Cahaba Valley region (Rome thrust sheet) in Alabama becomes progressively older to the southeast, and is the same age, within the same narrow conodont zone, as equivalent units in the clastic wedges in eastern Tennessee, but that the carbonate units underlying the shale at Calera are older than in the Tellico-Sevier belt in eastern Tennessee. Bergstrom (1973, p. 289) stated:

> "Recently collected samples from rocks mapped as the Lenoir Limestone immediately beneath the Rockmart Slate at Rockmart have yielded exactly the same Whiterockian-type of conodont fauna as that present in the calcarenites in the lower portion of the Lenoir Limestone at Calera. The fact that in the sections studied this fauna evidently ranges up to the very base of the Rockmart Slate without any intervening unit with North Atlantic province conodonts of the Eoplacognathus foliaceous Subzone suggests that the base of the Rockmart Slate at Rockmart is older than the base of the Athens in the Calera area. This conclusion is supported by graptolites collected from the Rockmart; at least at some localities they represent the Didymograptus murchisoni Zone (Jaanusson and Bergstrom, in preparation) and are therefore older than those collected from any other Middle Ordovician section in the southern Appalachians. The incomplete data so far available from the Rockmart region suggest the presence there of a shale wedge which is partly older than those in other areas in the southern Appalachians. This may be taken as an indication that this shale originally was deposited further (sic) away from the Midcontinent platform than, for instance, the Athens Shale at Calera and the Blockhouse Formation of the Tellico-Sevier belt."

Talladega Group

In the northernmost part of the Alabama crystalline terrane (fig. 1), the Talladega Group (Tull, 1982) is sandwiched between rocks of the Cambrian-Ordovician carbonate shelf sequence in the Rome thrust sheet on the north and the Hillabee greenstone in the Paulding, West Point, and Ropes Creek thrust sheets, or rocks of the Zebulon thrust sheet where the Hillabee is absent on the south. The Talladega Group consists of the Lay Dam Formation with its Cheaha Quartzite Member, and the Jemison Chert-Butting Ram Sandstone. The Talladega Group is bounded below by a structurally discordant contact where different clastic metasedimentary rocks of the group rest upon different units of the "Sylacauga marbles," (including the lowermost unit, the Jumbo Dolomite), which are now known to be mildly metamorphosed lower Paleozoic (mostly Knox Group) rocks of the carbonate shelf sequence in the Rome thrust sheet (Harris and others, 1984), including Chilhowee Group rocks which Tull (1982) and Tull and others (1985) have placed in the Kahatchee Mountain Group (Tull, 1982). Since the early 1960's this discordant contact has generally been interpreted as an unconformity (Shaw and Rodgers, 1963; Shaw, 1970, 1973; Gilbert, 1970, 1973; Carrington, 1973; Tull, 1978, 1979, 1982, 1984; Cook, 1982; Pendexter, 1982; Harris and others, 1984), the "pre-Lay Dam Formation unconformity" (Tull, 1982); early workers interpreted it as a thrust fault (McCalley, 1897; Prouty, 1916; Butts, 1926). We suggest that the evidence is equivocal, but that the relations of the Talladega Group to underlying rocks are remarkably similar to those of the Rockmart Slate. We interpret the Talladega Group to belong with the Valley and Ridge province rocks in a thrust slice in the Rome thrust sheet, and to have been overthrust by the Bill Arp and higher thrust sheets. The nearly north-south-trending thrust contact (extension of the Emerson fault) between the Talladega Group of the Valley and Ridge province in the Talladega thrust slice and Great Smoky Group (Ocoee Supergroup) rocks in the Bill Arp sheet in eastern Alabama just west of the Georgia-Alabama State Line is shown dashed and queried in figure 1. We have not yet done enough detailed mapping in that part of Alabama to revise the map relations between the Ocoee rocks and the Talladega Group; however, somewhere in the vicinity of the dashed and queried extension of the Emerson fault, the Talladega Group rocks of the Valley and Ridge province must become covered by the Bill Arp and higher sheets, just as their counterparts the Rockmart Slate, Tellico, and Chota Formations are to the northeast.

The Talladega Group, like the Great Smoky Group in the Bill Arp thrust sheet which locally overlies it, is composed entirely of metasedimentary rocks, so that in many places it is difficult to distinguish between the two (this has been part of the "Talladega problem"). The basal unit of the Talladega Group in Alabama is the Lay Dam Formation (Carrington, 1973; Tull, 1982), a thick sequence of slates, phyllites, metagraywackes, and metasiltstones (graded bedding is locally well-preserved). In the type area around Lay Dam on the Coosa River, the basal part of the Lay Dam Formation is a diamictite (Carrington, 1973; Telle and others, 1981; Telle, 1981; Tull, 1982) with fragments, chips, cobbles, and boulders of phyllite, quartzite, chert, granitic gneiss, and various metacarbonate rocks floating in a somewhat scaly, slightly arkosic phyllitic matrix. Many of the clasts have foliations or S-surfaces that terminate abruptly against the surrounding matrix. According to Tull (1982, p. 10), and Cook (1982, p. 50), the diamictites occupy higher positions in the Lay Dam Formation to the northeast.

Granitic gneiss clasts are fairly common in the Lay Dam diamictite near Lay Dam, and zircons from some of these clasts have yielded radiometric ages of about 1.1 b.y. (Telle and others, 1979). The zircon age and the size and angularity of some of the clasts led Telle and others (1979) and Tull (1982) to suggest that the granitic gneiss clasts were derived from a nearby source of Grenville-age basement. Telle and others (1979) suggested that this source lay to the northwest of the

present outcrop belt of the Lay Dam Formation and that the basement rocks were exposed in fault blocks. There are problems with this interpretation. So far as we know, there is nothing in the preserved sedimentary record in the Valley and Ridge sequences to the northwest to suggest that Grenville-age basement was exposed in fault blocks during the time of sedimentation (see below) of the Lay Dam Formation (Thomas and Neathery, 1980; Chowns and McKinney, 1980). Aeromagnetic data (Higgins and Zietz, 1975) indicate that the basement is relatively deep under the Valley and Ridge at the present time. However, Grenville-age basement gneisses (Corbin Gneiss, for example) are present beneath the Ocoee Supergroup rocks in the Bill Arp sheet to the southeast, and granitic gneisses are also present. We suggest that the granitic gneiss clasts in the Lay Dam diamictite were derived from the southeast as debris shed from granitic rocks in the thrust-up leading edge of the Bill Arp thrust sheet during sedimentation of the Lay Dam. We also suggest that the carbonate clasts in the Lay Dam were shed either from a shoved-up part of the shelf in front of the thrust-up edge of the Bill Arp sheet or, more likely, from parts of the carbonate shelf sequence on top of the Bill Arp thrust sheet (fig. 61). Mack (1985) has shown that most of the clastic sedimentary rocks in the southeasterly derived Middle Ordovician clastic wedge ("Blount clastic wedge" in Tennessee - Tellico-Talladega clastic wedge of this paper) are rich in K-feldspar probably derived from Grenville basement rocks, and were derived mostly from sedimentary rocks and low grade metapelitic slates and phyllites, thus supporting their derivation from thrust-up Bill Arp sheet rocks.

Harris and others (1984) recently reported the discovery of conodont elements of Silurian to Pennsylvanian morphotypes from laminated lower greenschist facies metasiltstone in the upper one-third of the Lay Dam Formation 5 km west of Jemison, Alabama. Fossils of probable Silurian or Early Devonian age have been reported from the Butting Ram Sandstone (probably Frog Mountain Sandstone) which overlies the Lay Dam Formation (Carrington, 1973). An Early and Middle Devonian age has long been established for the Jemison Chert which overlies the Butting Ram Sandstone (Butts, 1926; Carrington, 1973), and has since been confirmed by fossils we collected from the Jemison both west and east of the Town of Jemison. Based on these fossils and the earlier collections, J.T. Dutro, Jr., and E.L. Yochelson (written report, 7/13/83) assign an Oriskany age to the Jemison. Butts (1926) and Thomas and Neathery (1980) correlated the Jemison Chert with the Lower and Middle Devonian Frog Mountain Sandstone and Armuchee Chert. We agree, and suggest that the sedimentary facies change east of Jemison, Alabama, is the same as the facies change from chert to a clastic facies between the Armuchee and Frog Mountain in Georgia (Cressler, 197-). Everywhere but in the Talladega section, the Lower and Middle Devonian chert-sandstone sequence (Armuchee-Frog Mountain) is above a post-Silurian or post-Ordovician unconformity (Cressler, 1970; Drahovzal and Thomas, 1977; Thomas and Neathery, 1980). The Silurian-Pennsylvanian conodont elements (Harris and others, 1984) from the upper third of the Lay Dam Formation pose a problem, because they indicate that the upper part of the Lay Dam must be Silurian. Silurian rocks were previously unproven this far south or southeast in the Valley and Ridge province in Georgia and Alabama (Butts, 1926; Cressler, 1970; Drahovzal and Thomas, 1977; Chowns and McKinney, 1980; Thomas and Neathery, 1980). Part of the answer may lie in the undated Tellico and (or) Chota Formation equivalents at the top of the Rockmart Slate. The carbonate clast-containing diamictite horizon in the Lay Dam Formation may represent the same depositional environment as the Middle Ordovician Tellico and Chota Formations in Tennessee (Neuman, 1955), as the Chota and (or) Tellico Formations on top of the Athens Shale north of Chatsworth in northern Georgia, and as the Tellico Formation at the top of the Rockmart Slate (fig. 57). The Silurian-Pennsylvanian conodont elements (Harris and others, 1984) are from the upper third of the Lay Dam Formation, whereas the

diamictite horizon is at or near the base of the ~4.5 km thick section at the Coosa River, and isn't present in the 1 to 1.5 km thick section west of Jemison that contained the conodonts (Tull, 1982, p. 10). Regardless of whether the basal contact of the Lay Dam Formation with the Lower Ordovician (lower to middle Arenigian) Knox Group near Sylacauga ("Sylacauga Marble Group" of Tull, 1982) is an unconformity or a thrust (or both), the basal part of the Lay Dam there must be post-Early Ordovician. According to Cook (1982, p. 50, fig. 3), the diamictite horizon is more than 3 km above the base of the Lay Dam Formation near Sylacauga, in a total Lay Dam section that is approximately 4.6 km thick. It is thus probable, that the basal part of the Lay Dam Formation near Sylacauga may be as old as Middle Ordovician and perhaps roughly equivalent in age to (or only slightly younger than) the Rockmart Slate and Athens Shale (fig. 57). If the interpretation that the base of the Lay Dam Formation everywhere overlies an unconformity is valid (whether the Lay Dam has been thrust upon that unconformity or not), and if the diamictites mark a distinct horizon of deposition (depositional "event"), then the base of that horizon is probably diacronous, becoming progressively younger to the southwest. The hiatus between the base of the Lay Dam and the underlying carbonate rocks must also become greater to the southwest, because the unconformity apparently truncates progressively older carbonate units to the southwest - Middle Ordovician Lenoir Limestone near Rockmart, Georgia (Cressler, 1970); Lower Ordovician Knox Group rocks near Sylacauga, Alabama (Cook, 1982; Tull, 1982; Harris and others, 1984) and, Jumbo Dolomite (probably Shady Dolomite) beneath the Knox Group west of Sylacauga (Pendexter, 1982; Tull, 1982; fig. 60). A similar case can be made for the unconformity beneath the Armuchee Chert-Frog Mountain Sandstone horizon. The age of the upper part of the Rockmart Slate is unknown, but the Armuchee Chert-Frog Mountain Sandstone clearly rests in angular unconformity upon it, whereas near Jemison, roughly 150 km along strike, there appears to be a thick section of Silurian rocks, that are probably representative of a depositional environment similar to that of the Tellico Formation (formerly upper Rockmart), below the Jemison Chert, and though an unconformity beneath the Jemison is likely, probably neither the hiatus nor any angularity is as great as it is to the northeast (fig. 57). The apparent absence of the Frog Mountain Sandstone in northern Georgia also indicates diachronous depositional differences from northeast to southwest.

As early as 1956, Lochman had shown that the Middle Ordovician pelitic rocks in the western part of the northern Appalachians are contemporaneous with the Middle Ordovician carbonate shelf rocks there. Rodgers (1968) pointed out that similar relationships between Middle Ordovician deep-water dark shales and slates and Middle Ordovician shallow-water carbonate rocks of the carbonate shelf (or bank) exist along the eastern margin of the Valley and Ridge province throughout the Appalachians. He suggested that the carbonate shelf had subsided rapidly during the Middle Ordovician and that deposition of the deep-water pelites had transgressed over the edge of the shelf. Rodgers (1968, p. 146) stated:

> "The outlying masses (of slates and shales) may be allochthonous, having slid into their present location during the Middle Ordovician, when this part of the carbonate bank sank--we know it did, relatively at least, because the carbonate rocks there are overlain by Middle Ordovician black shale and then by eastward-derived graywacke turbidites. Uplifted source areas from which the masses could have slid are indicated both by these sediments and by erosional unconformities beneath Middle Ordovician rocks to the east (Zen, 1967, and this volume)."

Rodgers (1968, p. 145) considered the polymictic conglomerates (his "lime-breccias" and "lime conglomerates"), limey beds, and argillaceous limestone lenses to be

derived through "slumps from the edge of the carbonate bank, still not far away..." and that the areas where the dark pelites are juxtaposed against the carbonate shelf sequence mark the oceanward edge of the carbonate bank and approximately "what was then the eastern edge of sialic crust." However, in the southern Appalachians the polymictic conglomerates contain clasts that were clearly metamorphosed prior to sedimentation as recognized by Cressler (1970), Chowns and McKinney (1980), and Sibley (1983), and sandstone layers and lenses in the sequences that contain the conglomerates are feldspathic, suggesting that they were derived from crystalline rocks. Moreover, there is abundant evidence that the clastic sequences (clastic wedges) were derived from a source to the southeast (see above). We interpret the clastic rocks in the sequences to be derived from the shoved-up edge of the Bill Arp thrust sheet during early stages of its cratonward movement (fig. 61). The initiation of thrusting probably caused enough uplift at the leading edge of the sheet to form a land mass that isolated the starved (probably partly stagnant) basin where the dark, calcareous pelites were deposited. The polymictic conglomerates containing clasts representing most units of the carbonate shelf sequence and probably parts of the Chilhowee Group (Cressler, 1970), as well as metamorphic clasts from the Bill Arp sheet, and the conglomeratic sandstones were most likely derived from erosion of part of the carbonate shelf on top of the Bill Arp sheet that was thrust up with the Bill Arp thrust sheet (fig. 61). The clasts of reworked slate suggest that mildly metamorphosed basinward parts of the dark pelites were also buckeled up, or, more likely, thrust up, and subjected to erosion to supply material to the coarser sequences now above the dark pelites. As the thrust sheet encroached upon the carbonate shelf, the clastic wedges transgressed farther toward the craton, but at least locally (as appears to us to be the case with the Rockmart Slate), the incompetent shales (with the clastic wedges on top - in fact sedimentation was probably taking place on top of the wedges even as they were being thrust) detached and were shoved up the gentle slope of the shelf to become thrusts over the unconformity at the top of the Middle Ordovician shelf carbonate rocks. Continued movement folded the shelf carbonate sequence along with the parautochthonous and autochthonous sequences, and at the same time clastic wedges of molasse (Tellico-Talladega; Greensport, Colvin Mountain, Sequatchee) spread cratonward far beyond the limit of the dark pelites. The former edge of the carbonate shelf (Rodgers' carbonate bank edge) in the southern Appalachians must have been located far oceanward from the present location of the dark pelites. Late Paleozoic movement on the Emerson and Carters Dam faults has probably covered much of the sequences in the southernmost Appalachians.

The southwestward younging of the depositional environment of the polymictic conglomerate and diamictite horizons in the clastic sequences, from probably Upper Ordovician or Lower Silurian in the Rockmart, Georgia, area to Silurian in western outcrops of the Talladega Group, and the apparent decrease in age of rocks immediately below the unconformity underneath the clastic sequences, from the Middle Ordovician Lenoir Limestone near Rockmart, Georgia, to the Upper Cambrian-Lower Ordovician Knox Group near Sylacauga, Alabama, to the pre-Upper Cambrian (probably Lower Cambrian Shady Dolomite or its equivalent) Jumbo Dolomite farther west in Alabama, suggest that the initiation and advancement of thrusting of the Bill Arp sheet was diachronous and progressed like a triple point from northeast to southwest (fig. 57).

Summary Tables

Summaries of some of the salient characteristics of the Chickamauga terrane and the thrust sheets in the Rome-Kingston thrust stack are given in tables 6 and 7.

Table 6. Summary of the Chickamauga terrane.

Overlain by the Kingston thrust sheet

STRUCTURAL UNITS	STRATIGRAPHIC UNITS	GENERAL CHARACTERISTICS
Valley and Ridge province-Cumberland Plateau province Cambrian-Ordovician carbonate shelf sequence, Lower Silurian red-bed clastic sequence, Upper Devonian-Lower Mississippian black shales, Middle-Upper Mississippian shelf carbonate and marine shale sequence, and Pennsylvanian clastic sequence.	Rome Formation, Conasauga Formation, Knox Group (Copper Ridge Dolomite, Chepultepec Dolomite, Longview Limestone, Newala Limestone), Chickamauga Group (Alabama - Attalla Conglomerate, Stones River Formation, Nashville Formation, Inman Formation, Leipers Limestone), Chickamauga Supergroup (Georgia - Stones River Group: Pond Spring Formation, Murfreesboro Limestone, Ridley Limestone, Lebanon Limestone, Carters Limestone; Nashville Group: Hermitage Formation, Cannon Limestone, Catheys Formation), Sequatchie Formation, Red Mountain Formation, Chattanooga Shale, Maury Shale, Fort Payne Chert, Tuscumbia Limestone, Pride Mountain Formation, Hartselle Sandstone, Monteagle Limestone, Bangor Limestone, Pennington Formation, Pottsville Formation, Gizzard Group.	Cambrian through lower Middle Ordovician carbonate shelf (platform) sequence, overlain unconformably by Middle Ordovician carbonate shelf (platform) sequence, overlain unconformably by Lower Silurian red-bed sequence, overlain unconformably by thin but persistent Upper Devonian and Lower Mississippian chert, overlain by Mississippian carbonate shelf (platform) sequence, overlain by Mississippian marine shale, overlain by Pennsylvanian clastic sequence.

INTERPRETED ORIGIN

Shelf (platform) carbonate sequences and platform clastic sequences that are transitional between the North American craton and the Valley and Ridge basin.

Table 7. Summaries of the thrust sheets in the Rome-Kingston thrust stack.

Table 7a. Summary of the Kingston thrust sheet.

Overlain by the Clinchport thrust sheet

STRUCTURAL UNITS	STRATIGRAPHIC UNITS	GENERAL CHARACTERISTICS
Valley and Ridge province Cambrian-Ordovician carbonate shelf sequence, Lower Silurian red-bed clastic sequence, Upper Devonian-Lower Mississippian black shales, Middle-Upper Mississippian shelf carbonate and marine shale sequence, and Pennsylvanian clastic sequence.	Rome Formation, Conasauga Formation, Conasauga Group, Knox Group (Copper Ridge Dolomite, Chepultepec Dolomite, Longview Limestone, Newala Limestone), Lenoir Limestone, Chickamauga Group - Alabama; Chickamauga Supergroup - Georgia (Greensport Formation - northwestern facies, Colvin Mountain Sandstone - northwestern facies), Sequatchie Formation, Red Mountain Formation, Armuchee Chert, Frog Mountain Sandstone, Chattanooga Shale, Maury Shale, Fort Payne Chert, Floyd Shale, Bangor Limestone, Pennington Formation, Parkwood Formation, Pottsville Formation, Gizzard Group.	Cambrian through Middle Ordovician carbonate shelf (platform) sequence, overlain unconformably by Middle through Lower Silurian red-bed clastic sequence, overlain by Lower and Middle Devonian cherts, overlain unconformably by thin but persistent Upper Devonian and Lower Mississippian dark shales, overlain by Mississippian carbonate and marine sandstone and shale sequence, overlain by Pennsylvanian clastic sequence.

INTERPRETED ORIGIN

Shelf (platform) sequences at cratonward edge of most cratonward basin mixed with clastic synorogenic basin-fill deposits from thrust sheets to the present southeast and later chert, carbonate, marine shale and clastic sequences.

Underlain by the Chickamauga terrane

Table 7b. Summary of the Clinchport thrust sheet.

Overlain by the Rome thrust sheet

STRUCTURAL UNITS	STRATIGRAPHIC UNITS	GENERAL CHARACTERISTICS
Valley and Ridge province Cambrian-Ordovician carbonate shelf sequence, Ordovician-Lower Silurian red-bed molassic sequence, Lower and Middle Devonian cherts, Upper Devonian-Lower Mississippian dark shales, Middle-Upper Mississippian carbonate and marine shale sequence, and Pennsylvanian clastic sequence.	Rome Formation, Conasauga Formation, Conasauga Group, Knox Group (Copper Ridge Dolomite, Chepultepec Dolomite, Longview Limestone, Newala Limestone), Lenoir Limestone, Chickamauga Group - Alabama; Chickamauga Supergroup - Georgia (Greensport Formation - southeastern facies, Colvin Mountain Sandstone - southeastern facies), Sequatchie Formation, Red Mountain Formation, Armuchee Chert, Frog Mountain Sandstone, Chattanooga Shale, Maury Shale, Fort Payne Chert, Floyd Shale, Bangor Limestone, Pennington Formation, Parkwood Formation, Pottsville Formation, Gizzard Group.	Cambrian through Lower Ordovician carbonate shelf (platform) sequence, overlain unconformably by Middle Ordovician through Lower Silurian molassic red-bed sequence, overlain unconformably by Lower and Middle Devonian cherts, overlain by thin but persistent Upper Devonian and Lower Mississippian dark shales, overlain unconformably by Mississippian chert, overlain by Mississippian carbonate and marine sand and shale sequence, overlain by Pennsylvanian clastic sequence.

INTERPRETED ORIGIN

Carbonate shelf sequence built at edge of North American craton overlain by proximal parts of a clastic wedge derived from erosion of thrust sheets arriving from the present southeast and later chert, carbonate, and marine shale and clastic sequences.

Underlain by the Kingston thrust sheet

Table 7c. Summary of the Rome thrust sheet.

STRUCTURAL UNITS	STRATIGRAPHIC UNITS	GENERAL CHARACTERISTICS
Valley and Ridge province Cambrian-Ordovician carbonate shelf sequence, Middle Ordovician dark pelites, Lower and Middle Devonian chert, and Mississippian marine shale.	Chilhowee Group (Cochran, Nichols, Wilson Ridge, and Weisner Formations), Shady Dolomite, Rome Formation, Conasauga Group (Honaker Dolomite, Rogersville Shale, Maryville Limestone, Nolichucky Shale, Maynardville Limestone), Knox Group (Copper Ridge Dolomite, Chepultepec Dolomite, Longview Limestone, Mascot Limestone), Lenoir Limestone, Rockmart Slate, Athens Shale, Tellico Formation, Chota Formation, Talladega Group (Lay Dam Formation and its Cheaha Quartzite Member, Butting Ram Quartzite, Jamison Chert), Frog Mountain Sandstone, Fort Payne Chert, Floyd Shale.	Basin-fill clastic deposits overlain by Cambrian through Middle Ordovician carbonate shelf (platform) sequence, overlain unconformably (and locally overthrust) by Middle Ordovician dark pelites, overlain unconformably by Mississippian chert, overlain unconformably by Mississippian marine shale.

INTERPRETED ORIGIN

Basin-fill clastic deposits overlain by carbonate shelf sequence built at edge of North American craton, overlain by Middle Ordovician dark pelites, overlain by most proximal parts of a clastic wedge derived from erosion of thrust sheets arriving from present southeast and later chert and marine shale and clastic sequences.

PREVIOUS THRUST CONCEPTS

The classic thrust faults in the Valley and Ridge province have been known for many years (Hayes, 1891; Willis, 1893) and for nearly as many years debate raged over the mechanics of their formation and whether or not the Grenville-age basement was a passive or active participant in the process (Bucher, 1933; Rich, 1934; Cooper, 1964; Rodgers, 1964; Gwinn, 1970). The "no-basement" hypothesis for Valley and Ridge structure (Rodgers, 1964; Gwinn, 1970) now seems fairly well established, especially in light of recent geophysical evidence (for example: Cook and others, 1979; Harris and Bayer, 1979). Yet most of the geophysical methods, including deep seismic reflection profiling, are not designed to distinguish shallow structures very well, and though flat reflectors that have been interpreted as deep decollements (whatever their significance and whatever the underlying strata may be) can be detected, such features as folded thrust sheets may go undetected. Thus, there has been a tendency among many geologists to depict thrusts in the crystalline terrane of the southern Appalachians as long, continuous, southeastward dipping features that must root somewhere in the substrate or along the "master decollement." Some of these features have been elevated to such importance that they have begun to dominate interpretations of the structure and evolution of the southern part of the orogen. On the other hand, when flatter features are discovered, there has been a tendency to assume that they represent distinct allochthons. An example of one of these is Hatcher's (1978) "Alto allochthon" (also Hopson and others, 1985, and Dallmeyer and Hatcher, 1985) which probably doesn't exist as a separate allochthon, but is simply part of the Zebulon thrust sheet and smaller slices of the Bill Arp and Sandy Springs sheets outlined by a slice of Ropes Creek Metabasalt (with K-feldspar-poor plutons and iron formations) in the Ropes Creek thrust sheet to the southeast and by its juxtaposition against retrograded Brevard Zone rocks (mostly Bill Arp sheet rocks - fig. 1) rather than representing the "normal" situation in the crystalline terrane.

The "Hayesville thrust fault"

Hadley (in Hadley and Nelson, 1971) mapped a fault that passes through Hayesville, North Carolina, and separates "biotite gneiss and schist" from the "Great Smoky Group undivided." He did not name the fault. Hatcher, who considered the "Blue Ridge" to be divided into "belts" (or "docked" entities), stated (1978, p. 284, 285):

> "An important distinction between the western and eastern belts of the Blue Ridge is that the western is largely volcanic free, except for the Mount Rogers Formation volcanics and those in the lower Chilhowee (Unicoi Formation) in northeastern Tennessee and southwestern Virginia. The eastern belt contains abundant metavolcanic rocks. The eastern subdivision is bounded by the Fries fault from the Grandfather Mountain window northeastward. Rankin (1975) has suggested that the Fries fault extends southwestward into Georgia from the Grandfather Mountain window. The new 'Geologic Map of Georgia' (Pickering, 1976) (sic) does not show a fault in this area, except the Allatoona fault near Cartersville. But one particular contact in the Georgia Blue Ridge is probably a major fault, which can be traced into the boundary between the Ashland-Wedowee belt and the Talladega belt, and is probably also a major fault across Alabama (Neathery and Tull, 1975) (sic). I propose that this segment be called the Hayesville fault and the entire system the Hayesville-Fries thrust sheet. If the Hayesville-Fries thrust sheet extends to the Coastal Plain overlap, it is as extensive as the Blue Ridge thrust farther west and probably tectonically just as important.

> Several other lines of evidence point toward a major thrust sheet in the eastern Blue Ridge. Most of the ultramafic rocks occur in this belt (as first pointed out by Rankin, 1975, p. 323), along with all the Paleozoic granitic plutons. Throughout most of this belt, there is also a paucity of 'Grenville' basement orthogneisses..."

Based on the Geologic Map of Georgia (Georgia Geological Survey, 1976), one might generalize broadly and say that most of the metavolcanic and ultramafic rocks, and nearly all of the Paleozoic granitic plutons (transported in thrust sheets above the Bill Arp thrust sheet) occur in this eastern terrane, and a likely boundary from which to extrapolate would be the minor fault that Hadley (Hadley and Nelson, 1971) mapped in Hayesville, North Carolina.

Hatcher's (1978) Hayesville fault has been widely accepted without much additional mapping. It is shown, just as he depicted it on Williams' (1978) "Tectonic lithofacies map of the Appalachian orogen," and in numerous subsequent publications dealing with the southern Appalachians. In Georgia, McConnell and Costello (1980) following Hatcher's depiction of the "Hayesville fault," renamed Hurst's (1973) Allatoona fault "the Allatoona-Hayesville fault," though they did not show how it connected with the fault at Hayesville, North Carolina. More recently, McConnell and Abrams (1984, p. 9) depicted the "Allatoona fault" and the "Hayesville fault as different faults," whereas Abrams and McConnell (1984, p. 1522) depicted the "Allatoona-Hayesville fault" as the same fault much as Hatcher (1978, 1981) and Williams and Hatcher (1982, 1983) had depicted it.

In 1978, Dallmeyer and others showed that distinctive formations of the Great Smoky Group map directly across the trace of the "Hayesville fault" as depicted by Hatcher (1978). Despite Dallmeyer and others' work, Hatcher and Odom (1980, p. 322) suggested that the fault is a "cryptic suture," and in 1981, Hatcher (p. 493) stated:

> "The Hayesville fault is a fundamental boundary which separates a terrane of mafic volcanic and ultramafic rocks, metasedimentary rocks, granite plutons and rare continental basement rocks to the E (sic) from a metasedimentary nonvolcanic terrane which is easily tied to continental basement (Hatcher, 1978)."

Williams and Hatcher (1982, 1983) shifted the depicted position of the Hayesville fault to the east in western Georgia and eastern Alabama, and depicted all of the terrane to the west of it (including part of the Ocoee Supergroup) as the "Appalachian Miogeocline."

Our work confirms the conclusion of Dallmeyer and others (1978, p. 31) that the Hayesville fault as defined and depicted by Hatcher (1978a, 1981), Williams (1978), Hatcher and Odom (1980), and Williams and Hatcher (1982, 1983) is neither a "cryptic suture," nor a "fundamental boundary," because it does not exist in Georgia and Alabama (and, as they define it, probably not to the northeast in North Carolina). Mafic metavolcanic rocks of the Zebulon Formation in the Zebulon thrust sheet, mafic metavolcanic rocks of the Ropes Creek Metabasalt (locally with the distinctive iron formations) in the Ropes Creek thrust sheet, and mafic and ultramafic plutonic rocks of the Soapstone Ridge thrust sheet are present as infolded slices both east and west of the proposed trace of Hatcher's Hayesville fault - to the west, they are present almost to the border of the crystalline terrane near the Carters Dam fault (fig. 1). In the complex area east of Blairsville, Georgia, mafic metavolcanic rocks in the Zebulon thrust sheet underlie the West Point melange and Ropes Creek Metabasalt (see section on West Point melange); the areas to the east and west are mostly underlain by rocks of the Bill Arp thrust sheet,

which lack volcanic components (including the Richard Russell thrust slice), but scattered infolded slices of higher thrust sheets containing mafic volcanic components occur throughout. The faults that have been called the "Hayesville," or "Allatoona-Hayesville fault" to the southwest in Georgia and Alabama are simply the northwesternmost infolds of the Ropes Creek or (and) Paulding thrust sheets (+ West Point thrust sheet). We therefore suggest that the names Hayesville fault, Allatoona-Hayesville fault, and Hayesville or Hayesville-Fries thrust sheet should not be used in Georgia and Alabama.

THRUSTING

Major thrusting in the southernmost Appalachians in Georgia and Alabama appears to have taken place almost continuously from about Middle Ordovician to Permian time. The youngest major thrust faults are those in the Valley and Ridge province (Rome, Clinchport, Kingston); the Rome thrust fault serves as an example. The Rome fault (figs. 1 and 2) has thrust the Cambrian-Ordovician carbonate shelf sequence upon rocks as young as Late Mississippian, but has been folded along with Lower Pennsylvanian rocks. There is evidence (Cressler, 1970) that thrusting on the Rome fault took place during formation of the major folds in the underlying rocks. Cressler (1974, p. 31) estimated a minimum of 5 to 10 miles (~8.5 to 17 km) displacement on the Rome fault based on remnants of the Rome thrust sheet found west and northwest of the present trace of the fault. Actual displacement on the fault is probably on the order of many tens of kilometers. Where shale has been thrust upon shale the Rome fault is marked by a zone of claylike gouge generally less than 6 centimeters thick, but where harder rocks such as siltstone or limestone are in contact there is generally a zone (tectonic melange) about 2 to 4 meters thick that is a mixture of rocks from above and below (Cressler, 1970, p. 52; 1974, p. 31). Cressler (1974, p. 31) described the fault as follows:

> "The Rome Fault is a flat-lying bedding-plane thrust that originated in shale of the Conasauga or Rome Formations. The fault developed a frontal prow that angled steeply upward, cutting through the overlying formations until it reached the Floyd Shale. There it flattened out and continued its westward slide. The Conasauga, having been uplifted 7,000 feet along the frontal prow of the fault, continued to push westward as a flat thrust sheet. Even with all this movement, the fault zone in most places consists of only 1 or 2 inches of claylike gouge."

Probably about the same age or only slightly older than the Rome fault, the Emerson thrust fault (fig. 1) has emplaced the metamorphic rocks in the Georgiabama thrust stack upon the Rome thrust sheet. The Emerson fault has emplaced rocks as old as the late Precambrian Great Smoky Group upon rocks as young as the Lower Mississippian (Chesterian) Floyd Shale. The amount of displacement on the Emerson fault is unknown, but is probably on the order of many tens of kilometers rather than hundreds of kilometers (also see Tull, 1984). The Emerson fault is locally marked by a thin silicified breccia; mylonitic rocks have not been found along the fault.

The major fault that forms the boundary between the crystalline terrane and the Valley and Ridge province north of Emerson, Georgia (fig. 1), has generally been called the Great Smoky fault (McConnell and Costello, 1982; Crawford and Cressler, 1982; and references in both), and assumed to be the same as the Great Smoky fault in eastern Tennessee. Moreover, with the exception of Kesler (1950) and Hurst (1973), most workers have considered the "Great Smoky" and Emerson (formerly Cartersville) faults the same fault (McConnell and Costello, 1982, and references therein). Recent detailed work by Crawford and Cressler (1982; Cressler

and others, 1979) has shown that the east-northeast-trending Emerson fault has overridden the nearly north-south-trending "Great Smoky" fault and other structures and rock units with the same general trend near Emerson, Georgia, thereby precluding the equality of the two faults. More recently, Costello and McConnell (1983) suggested that the nearly north-south-trending fault that has generally been called the "Great Smoky fault" in Georgia is correlative with the Miller Cove thrust fault in Tennessee, rather than with the Great Smoky fault. McConnell and Costello (1984, p. 264) depict the fault as the "Blue Ridge thrust," but state in a footnote that "the major fault separating Ocoee Supergroup rocks from Chilhowee Group rocks is now interpreted to be only the Cartersville fault. "Still more recently, McConnell and Abrams (1984, p. 9, fig. 2) and Abrams and McConnell (1984, p. 1522) depict the "Cartersville fault" as the boundary between the Valley and Ridge and "Blue Ridge" from eastern Alabama through most of Tennessee, and they use the name Great Smoky fault for the Johnson Mountain fault of Cressler and others (1979), which is located entirely in the Valley and Ridge province and has thrust the Cambrian Rome Formation over the Cambrian Conasauga Formation. King (1964, p. 100) pointed out the difficulties in identifying the Great Smoky fault outside of its type area in eastern Tennessee. In light of all of this confusion, we feel that the fault in northwest Georgia can neither be correlated directly with the Great Smoky fault nor the Miller Cove fault with any confidence at the present time, and suggest that the fault in Georgia, where we have some control, be called the Carters Dam fault for Carters Dam (fig. 1) where it is well exposed in the spillway cuts (fig. 58).

The exposures at Carters Dam show that the Carters Dam fault is marked by a zone of tectonic melange as much as 30 meters wide. The lower two meters of this melange is a scaly "gouge" with clasts of sheared Great Smoky Group rocks from above and of Conasauga Formation rocks from below (fig. 58); the matrix also appears to be derived from a mixture of rocks from above and below (Cressler, 1974, p. 33). The bulk of the melange above this zone consists of intensely sheared and disrupted (fig. 58) quartz-granule metaconglomerate of the Great Smoky Group exposed around the top of the dam.

The amount of displacement on the Carters Dam fault is unknown. However, it has transported late Precambrian Ocoee Supergroup rocks onto the Cambrian-Ordovician carbonate shelf sequence and younger rocks in the Rome thrust sheet, suggesting at least many tens of kilometers displacement. Regardless of the amount of displacement, the Emerson and Carters Dam faults have accounted for final emplacement of the Georgiabama thrust stack upon the Rome thrust sheet in the Rome-Kingston thrust stack through Georgia and Alabama.

Thrusting within the Georgiabama thrust stack

The Georgiabama thrust stack appears to be divisible into three main sequences of sheets by differences in metamorphic and deformational histories, and also by differences in deformation of the sheets northwest and southeast of the Brevard Zone. The autochthogenetic Bill Arp thrust sheet has apparently had a different history from the overlying Zebulon, Clairmont, Wahoo Creek, Atlanta, and Promised Land thrust sheets, and these five sheets differ from the overlying Sandy Springs, Paulding, West Point, Ropes Creek, and Soapstone Ridge thrust sheets. The most striking differences occur at or just southeast of the Brevard Zone and the line of large synforms that are perhaps best represented by the Newnan Tucker synform (fig. 3). Northwest of the synforms and the Brevard Zone the Sandy Springs and higher sheets, as well as the underlying Zebulon and Bill Arp sheets, are tightly folded in generally northeast-trending, northwest-verging isoclines with axial traces that are in general nearly parallel to the axial trace of the Newnan-Tucker synform. However, to the southeast (fig. 3), the Sandy Springs and higher sheets rest

discordantly athwart contacts of units involved in the northeast-trending synforms and appear to have been involved in fewer folding events than the underlying rocks. These relations strongly suggest that the Newnan-Tucker and other cogenetic synforms along strike formed (or partially formed) before arrival of the Sandy Springs and higher sheets and before final development of the major northeast-trending folds to the northwest. Thus, there appears to be a fundamental tectonic change at, or more likely just southeast of, the Brevard Zone.

Despite their position at the bottom of the Georgiabama thrust stack, rocks of the Bill Arp thrust sheet northwest of the Brevard Zone are apparently less deformed than the rocks of the overlying Zebulon, Sandy Springs, Paulding, Ropes Creek, and Soapstone Ridge sheets; rocks of the Bill Arp sheet northwest of the Brevard apparently have at least one less fold generation than the five next overlying thrust sheets. Therefore, we suggest that the rocks of the Bill Arp sheet were neither intensely folded nor much metamorphosed when the overlying sheets were emplaced upon them, whereas the rocks of the Zebulon through Promised Land sheets were already metamorphosed and intensely folded before emplacement upon the Bill Arp sheet.

We have found no firm criteria to indicate whether the Zebulon, Clairmont, Wahoo Creek, Atlanta, and Promised Land thrust sheets were emplaced upon the Bill Arp sheet as an assembled five-sheet stack or separately in sequence. The fact that the Zebulon thrust sheet extends almost as far to the north and northwest as the Bill Arp thrust sheet (fig. 1), and locally almost to the Valley and Ridge province, seems to suggest that it may have arrived slightly ahead of, and separately from the Clairmont and higher sheets. Moreover, the fact that the Clairmont, Wahoo Creek, Atlanta, and Promised Land sheets are only present southeast of the Brevard Zone, as much as 50 kilometers southeast and south of the present northernmost and northwesternmost extent of the Zebulon thrust sheet, suggests their arrival upon the Zebulon as a separate four-sheet thrust stack.

The presence of the upper Precambrian Great Smoky Group, and the uppermost Precambrian-Lower Cambrian(?) Chilhowee, and Ellijay Groups in the Bill Arp thrust sheet places a lower constraint on the time of emplacement of the overlying Zebulon, Clairmont, Wahoo Creek, Atlanta, and Promised Land sheets. Lack of debris from the overlying thrust sheets in the Great Smoky and Ellijay metasedimentary sequences, lack of melanges or other indications of severe tectonic disruptions of sedimentation, and the widespread preservation of graded bedding and other more delicate sedimentary structures in the rocks (Hurst, 1955; Mellen, 1956; Webb, 1958; Hurst and Schlee, 1962; p. 16, this paper) suggests that these Ocoee rocks were well-consolidated before final emplacement of the Zebulon, Clairmont, Wahoo Creek, Atlanta, and Promised Land thrust sheets. Therefore, these five sheets were probably emplaced upon the Bill Arp sheet after the Precambrian, and probably after the Early Cambrian (see below).

Because it rests in discordant thrust contact upon the rocks of the Bill Arp, Zebulon, Clairmont, Wahoo Creek, Atlanta, and Promised Land thrust sheets, but has been folded along with the Bill Arp and Zebulon sheets northwest of the Brevard Zone, the Sandy Springs thrust sheet must have been emplaced after the folding that produced the Newnan-Tucker synform, but before the completion of the northeast-trending folds northwest of the synform. Thus, the Sandy Springs and higher thrust sheets must have overridden the leading edge of the Clairmont-through-Promised Land sheets.

The upper limit for time of emplacement of the Zebulon, Clairmont, Wahoo Creek, Atlanta, and Promised Land sheets upon the Bill Arp sheet, and emplacement of the overlying Sandy Springs sheet, is best set by the time of emplacement of the overlying Paulding, West Point, Ropes Creek, and Soapstone Ridge thrust sheets. In Alabama (fig. 1), rocks in the leading edge of the Paulding, West Point, and Ropes

Creek sheets (Hillabee greenstone) rest in thrust contact upon the Lower and Middle Devonian (Ozarkian-Onandagan) Jemison Chert and some of its equivalents (Armuchee Chert-Frog Mountain Sandstone equivalents), clearly establishing that these sheets were emplaced in their present tectonostratigraphic positions after the Middle Devonian, and establishing that the underlying (Zebulon through Sandy Springs sheets) were emplaced earlier.

Thus, there is evidence that the lower sheets in the Georgiabama stack were emplaced upon the lowest (Bill Arp) sheet between Middle Ordovician and Middle Devonian time. The Athens Shale, Rockmart Slate, Chota and Tellico Formations, the Talladega Group, and the rocks in the Rome-Kingston thrust stack provide further clues for interpreting the time of emplacement of the Zebulon-through-Sandy Springs sheets.

The Cambrian-Ordovician carbonate shelf sequence in the Rome-Kingston thrust stack provides evidence of the time of thrusting in the Georgiabama thrust stack. There is abundant evidence that this sequence represents the building of an enormous carbonate bank that grew essentially uninterupted except for periodic influxes of mostly fine-grained clastic material from the craton (such as that in the Rome and Conasauga Formations) from the time of deposition of the Lower Cambrian Shady Dolomite (itself deposited on top of tidal flat and beach-barrier island deposits of the Chilhowee Group - Mack, 1980) through the time of deposition of the Upper Cambrian and Lower Ordovician Knox Group (Butts, 1926; Rodgers, 1953, 1968, 1982; Cressler, 1970, 1974; Palmer, 1971; Thomas and Neathery, 1980). A regional unconformity truncates the top of the Knox Group (Colton, 1970; Thomas and Neathery, 1980) and records a major regression that marked the beginning of instability of the shelf and signaled the first movement of the Bill Arp thrust sheet, probably in response to arrival of higher sheets in the Georgiabama stack upon the oceanward parts of that sheet. From Middle Ordovician time to Early Devonian time the shelf was unstable and was alternately receiving clastic material from the southeast and being buckled up and eroded. The end of deposition on the southeastern part of the shelf was established with the arrival of the Paulding and Ropes Creek thrust sheets upon the Lower and Middle Devonian Jemison Chert (Armuchee Chert-Frog Mountain Sandstone).

METAMORPHISM AND DEFORMATION

As Rodgers (1982, p. 237-238) recognized, the movement of the great stacks of mostly crystalline thrust sheets* "was what compressed and deformed the rocks of the folded belt (Valley and Ridge of this paper), producing all of the folds and thrust sheets observed there." We suggest that the slow but relentless collisional impact and the continuously cratonward-advancing thrust sheets also produced all of the deformation and metamorphism in the crystalline terrane; and that the metamorphism was the result not only of the overpressures and depths of burial caused by the thick stack of moving thrust sheets, but also by the blanketing effect of the stack (see Waldbaum, 1971, especially p. 546). In general then, metamorphic effects should decrease toward the leading edges of thrust sheets or thrust stacks and towards the top of the thrust stack sequence, whereas tight folds with axes approximately normal to the direction of movement of the thrust sheets and thrust stacks should increase towards the leading edges, especially if these leading edges were relatively thin. This picture is oversimplified given the complexities of the southern Appalachians, but fits well in a general way with the metamorphic and structural relations in Georgia and Alabama.

* Rodgers (1982, p. 237), following the COCORP interpretations of what was previously known of the geology of the crystalline part of the southern Appalachians, considered the crystalline rocks to have moved as a single block on the "major fault at the north-west front of the Blue Ridge..." for as much as 200 kilometers.

One of the most intriguing metamorphic features of the Georgia and Alabama crystalline terrane is the difference in metamorphic grade between many of the rocks in the Paulding, Ropes Creek, and Soapstone Ridge thrust sheets and the rocks in the thrust sheets that underlie them. Metamorphosed mafic rocks in the Paulding, Ropes Creek, and Soapstone Ridge sheets are commonly chloritic to some extent, epidote-rich in many outcrops, and locally have tremolite or actinolite as their principal ferromagnesian mineral (Griffin, 1951; Carrington and Wigley, 1964; Hurst and Crawford, 1970; Bentley and Neathery, 1970; Reynolds, 1973; Hurst and Jones, 1973; Neathery, 1975; Tull and others, 1978; Tull and Stow, 1980a; Rheams, 1982; Stow and others, 1984). Metamorphosed mafic rocks in the underlying Zebulon, Clairmont, Wahoo Creek, Atlanta, Promised Land, and Sandy Springs thrust sheets are unchloritic, generally less rich in epidote, and almost invariably have hornblende as their principal ferromagnesian mineral. Most workers have attributed the lower grade rocks in the Paulding, Ropes Creek, and Soapstone Ridge sheets to retrogressive chloritization because these sheets also have rocks that appear to be at amphibolite grade (although many of these have small amounts of chlorite in the mode) and some contain pyroxenes. It is often difficult to distinguish between mafic rocks that have been prograded to amphibolite grade and later retrograded to chlorite grade and mafic rocks that have been prograded or partly prograded only to chlorite grade. The mafic rocks of the Paulding, Ropes Creek, and Soapstone Ridge sheets have some of the characteristics of both. In many parts of the sheets, rocks with greenschist facies mineral assemblages, rocks with amphibolite facies assemblages, and rocks with assemblages belonging to both facies appear randomly intermixed, suggesting retrogression of rocks originally metamorphosed to the amphibolite facies. Even the lowest grade mafic rocks near the leading edge of the Paulding and Ropes Creek thrust sheets (including the Hillabee greenstone - Griffin, 1951; Carrington and Wigley, 1967) locally contain hornblende and metamorphosed felsic and silicic volcaniclastic rocks within the predominately mafic sequences have large, locally euhedral hornblende crystals which Tull and others (1978, p. 20-22) interpreted as porphyroclasts of "relict phenocrysts from the original igneous rock." However, most of these hornblende crystals, and particularly the subhedral and euhedral ones, are not porphyroclasts. They may originally have been igneous phenocrysts, but the fact that some of them appear to have grown and pushed apart the enclosing foliation planes forming pressure shadows (Tull and others, 1978, p. 23, fig. 8) strongly suggests that they are porphyroblasts formed during amphibolite facies metamorphism.

The bulk of evidence indicates that most of the rocks in the Paulding, Ropes Creek, and Soapstone Ridge thrust sheets were metamorphosed to amphibolite grade and later partly retrograded to chlorite grade. We suggest that rapid and incomplete prograde metamorphism of these rocks took place during early stages of plate collision near their original tectonic settings, and that this was followed fairly rapidly by generally incomplete retrogressive metamorphism during transport.

Also generally at chlorite grade and not intensely deformed are the metavolcanic and metasedimentary rocks in the Little River allochthon. The overlying Northern Florida platform sequence is unmetamorphosed. These were probably the last stack of rocks to arrive in their present position on top of the Georgiabama thrust stack before collision ceased. Their high structural position and the waning pressure of collision probably account for their generally low grade and lack of strong deformational features.

The thrust sheets in the lower part of the Georgiabama thrust stack (Bill Arp through Sandy Springs) southeast of the Brevard Zone are ubiquitously at sillimanite grade. Northwest of the Brevard, in the Austell-Frolona anticlinorium (figs. 1 and 3), the Frolona Formation, which underlies the Bill Arp Formation in

the Bill Arp thrust sheet, is at kyanite grade, and the Bill Arp Formation is presumed to be at kyanite grade, although alumino-silicate index minerals are unknown. About 25 kilometers to the northwest, where Bill Arp thrust sheet rocks (Great Smoky Group undivided) reappear from beneath the Zebulon, Paulding, Ropes Creek, and Soapstone Ridge thrust sheets (fig. 3), they are mostly at biotite-grade, and the grade appears to decrease to the northwest until chlorite grade rocks are present just southeast of the Emerson fault (also see Webb, 1958). To the southwest of the area of figure 3, where wider outcrop belts of Bill Arp thrust sheet rocks occur (fig. 1) between the Emerson fault and the leading edges of the Zebulon, Paulding, Ropes Creek, and Soapstone Ridge thrust sheets, the zone of chlorite grade rocks is also wider, and still farther to the southwest, where the Talladega Group intervenes between the Talladega thrust fault and the leading edges of the higher thrust sheets (fig. 1), the zone of chlorite-grade rocks is wider still. A wider zone of chlorite and biotite grade rocks of the Bill Arp thrust sheet also occurs west of the last erosional remnants of the Zebulon thrust sheet in northern Georgia (fig. 1; also Smith and others, 1969, and Hurst, 1973), along the western flank of the Murphy synclinorium.

Rocks of the Zebulon thrust sheet maintain kyanite grade, or locally staurolite grade assemblages (or both) from where they emerge from beneath the leading edge of the Clairmont melange and higher sheets to its present leading edge (fig. 1). Throughout this extent the Zebulon sheet was structurally overlain by the Paulding, Ropes Creek, and Soapstone Ridge thrust sheets. Thus, again there appears to be a relation between the presence and thickness of overlying thrust sheets and degree of metamorphism; where the Zebulon sheet was overlain by the thick Clairmont, Wahoo Creek, Atlanta, and Promised Land thrust sheets it is at sillimanite grade, but where it was overlain only by the Sandy Springs, Paulding, Ropes Creek, and Soapstone Ridge thrust sheets or by just the Paulding, Ropes Creek, and Soapstone Ridge sheets it is at kyanite or staurolite grade.

Perhaps the most dramatic evidence suggesting a relation between overlying thrust sheets and degree of metamorphism lies in the Jemison Chert and "Sylacauga marbles" near the northwestern edge of the crystalline terrane in Alabama (fig. 1). We have already described how the Jemison Chert can be traced from an unmetamorphosed rock to a metamorphic tectonite, with the change taking place almost exactly where the Hillabee greenstone first rests in thrust contact upon it. A similar situation exists in the "Sylacauga marbles." These "Sylacauga Marble Group" rocks are now known to belong to the Valley and Ridge province Cambrian-Ordovician carbonate shelf sequence, yet they appear to have been mildly metamorphosed because they were once structurally overlain by the Talladega Group.

Variations in style and intensity of deformation also appear to be related to the thrust sheets and their emplacement. Southeast of the leading edges of the Clairmont melange and Wahoo Creek thrust sheets (figs. 1 and 3) rocks of the Zebulon, Clairmont melange, Wahoo Creek, Atlanta, and Promised Land thrust sheets have at least five generations of folds (Atkins and Higgins, 1980) and have been folded into large, northwest-verging, tight to isoclinal, moderately to steeply inclined (Fleuty, 1964) synforms, such as the Newnan-Tucker synform, that must have formed slightly before or during the later stages of emplacement of the overlying Sandy Springs, Paulding, Ropes Creek, and Soapstone Ridge thrust sheets which discordantly overlie the synforms and the earlier folds (figs. 1 and 3). Southeast of the Newnan-Tucker synform and similar synforms roughly along strike, other large synforms, such as the Griffin synform containing the Zebulon and Atlanta thrust sheets, and large antiforms, such as the Ola anticlinorium containing the Zebulon and Bill Arp thrust sheets, become more open and more upright (fig. 61o). We attribute the differences to a rumpling effect in the leading edge of the moving stack of thrust sheets (much as a pushed carpet becomes more tightly folded at its

leading edge), an effect that naturally decreases away from the front. The cause and effects are thus quite similar to the thrust-caused folds in the Valley and Ridge province (Cressler, 1970; Rodgers, 1982).

Northwest of the leading edge of the Clairmont or Wahoo Creek thrust sheet (figs. 1 and 3), the Sandy Springs, Paulding, Ropes Creek, and Soapstone Ridge thrust sheets, which hardly participated in the northeast-southwest-trending folding that produced the Newnan-Tucker line of synforms to the southeast, and to a slightly lesser extent the Bill Arp and Zebulon sheets as well, are folded into northwest-verging, tight to isoclinal, gently to steeply inclined folds that become closer spaced to the northwest toward the leading edges of the sheets. Here again the pushed-carpet analogy seems to apply, with the thick, already folded (Newnan-Tucker and similar synforms) Promised Land and underlying sheets forming the more solid pushing-block. As with the metamorphic scenario, this picture is oversimplified, chiefly because the folding probably took place continuously with formation of folds in one sector of the stack overlapping and overtaking the formation of folds in another sector, as appears to have happened in the Valley and Ridge province (Cressler, 1970, 1974).

Variations in metamorphic effects upon K-Ar and Ar^{40}-Ar^{39} ages of micas also appear to be related to thicknesses of overlying thrust sheets and stacks. As Hurst (1970, p. 394, fig. 5) recognized, K-Ar dates of biotite and muscovite are, in general, older to the northwest and younger to the southeast across the crystalline terrane in Georgia, Alabama, South Carolina, and parts of Tennessee and North Carolina, until older ages reappear in the Little River allochthon. Hurst (1973, p. 664) stated:

> "An areal plot of available radiometric ages for the southeastern United States shows a well defined pattern. For micas the older ages are along the west side of the Blue Ridge belt. Eastward the ages are progressively though erratically younger toward the zone characterized by 250 m.y. ages, which extends northeast-southwest through Raleigh, North Carolina, and Elberton, Georgia"

Thus, in a general way, it appears that where the rocks were covered by numerous thick thrust sheets the metamorphic effect has been a lowering of K-Ar ages of micas, and where the rocks were covered only by a few sheets and (or) by the thinner leading edges of sheets older K-Ar ages of micas have been retained.

Ar^{40}-Ar^{39} plateau ages of hornblende and muscovite (Dallmeyer and Hatcher, 1985) from rocks of the Zebulon thrust sheet and the Ropes Creek thrust sheet in northeast Georgia (in the area of the so-called "Alto allochthon," see above) also support a relation between thickness of overlying thrust sheets and stacks and the ages. The oldest ages are from the Ropes Creek Metabasalt in the Ropes Creek thrust sheet ("Chauga belt" of Dallmeyer and Hatcher, 1985) near the top of the Georgiabama thrust stack, and younger ages are from the Zebulon Formation in the Zebulon thrust sheet (rocks of the "Alto Allochthon" of Dallmeyer and Hatcher, 1985) near the bottom of the Georgiabama thrust stack. In addition, a comparison of the ages from the Zebulon rocks in northeast Georgia with those obtained by Dallmeyer (1978) from the Atlanta, Georgia, area also supports a relation between thickness of thrust sheets and Ar^{40}-Ar^{39} plateau ages. The Zebulon rocks in northeast Georgia have older plateau ages than the rocks in the Atlanta area (Dallmeyer, 1978; Dallmeyer and Hatcher, 1985). The Zebulon rocks dated in northeast Georgia were probably never covered by the thick Clairmont, Wahoo Creek, Atlanta, and Promised Land thrust sheets (fig. 1), whereas the rocks dated in the Atlanta area were covered by one or more of these sheets.

THE BREVARD ZONE

The Brevard Zone is a narrow zone of sheared and low-grade-appearing rocks that extends from beneath the Coastal Plain in Alabama to southern Virginia. There have been more than twenty different interpretations and combinations of interpretations of the nature of this controversial zone (see reviews and discussions in: Medlin and Crawford, 1973; Roper and Justus, 1973; Rankin, 1975). Many of these interpretations have evoked thrust faulting or strike-slip faulting, or some combination of the two to explain the zone (Jonas, 1932; Crickmay, 1952; Reed and others, 1961; Reed and Bryant, 1964; Overstreet and Bell, 1965; Higgins, 1966; Dunn and others, 1968; Bentley and Neathery, 1970; Bryant and Reed, 1970a, 1970b; Reed and others, 1970; Conley and Henika, 1970; Hatcher, 1970, 1971a), but nearly as many have emphasized the stratigraphic nature of the zone (Keith, 1905, 1907; King, 1955; Shufflebarger, 1961; Hurst and Crawford, 1964; Cazeau, 1967; Hatcher, 1969, 1970; Hurst, 1970, 1973; Medlin and Crawford, 1973; Crawford and Medlin, 1973, 1974). Still other interpretations involve some form of root zone (Eardley, 1954; Burchfiel and Livingston, 1967; Livingston and Burchfiel, 1968; Reed and others, 1970; Bryant and Reed, 1970; Hatcher, 1971b; Butler, 1971), or a "Caledonide-like Abscherungzone" (Griffin, 1969), or a paleo-subduction zone (Watkins and Huggett, 1970; Watkins, 1971a, 1971b), or a complicated polytectonic zone in which isoclinal folds are formed and then sheared out during plate collision(s) (Dunn and others, 1968; Butler, 1973; Roper and Justus, 1973), or the suture zone between a Piedmont island arc and the North American continent, which was also the root zone for Blue Ridge thrust sheets (Odom and Fullagar, 1973), or the transported suture along which the proto-Atlantic Ocean finally closed (Rankin, 1975).

Perhaps not surprisingly, our work indicates that the Brevard Zone is probably a combination of many of the previous interpretations in one sense or another, except for the root zone, Abscherungzone, transported suture, and paleo-subduction zone interpretations. Our work shows that throughout Georgia and Alabama at least, identical stratigraphic sequences in the Bill Arp, Zebulon, Sandy Springs, Paulding, Ropes Creek, and Soapstone Ridge thrust sheets are found on both sides of the Brevard Zone (figs. 1 and 3), and that the only major sequences found on one side of the zone but not on the other are those in the Clairmont Wahoo Creek, Atlanta, and Promised Land thrust sheets, and in the Little River thrust stack (excluding of course rocks in the Valley and Ridge province, including the Talladega Group, Rockmart Slate, and Athens Shale). This precludes the Brevard Zone being a fault of great magnitude, as predicted by Hurst (1970, 1973). It also nullifies the concept that the Blue Ridge and Piedmont are separate <u>geologic belts</u>, as pointed out earlier by Medlin and Crawford (1973) and Crawford and Medlin (1973). Our work shows that <u>no</u> major thrust sheets in Georgia and Alabama are rooted in the Brevard Zone or anywhere near it.

The works of Hurst and Crawford (1964), Hatcher (1969), Hurst (1973), Medlin and Crawford (1973), Crawford and Medlin (1973, 1974), Kline (1980), and our own work, clearly show that mappable stratigraphic sequences are present in the traditional Brevard Zone. We go one step farther here, and suggest that different sequences within the zone are different thrust sheets in the Georgiabama thrust stack that have been sheared and generally incompletely retrogressed. The rocks of the Brevard Zone were considered low-grade (and prograde) phyllites and schists by Kieth (1905, 1907), and Hatcher (1969, 1970). Our work confirms that of Jonas (1932) and Reed and Bryant (1964), that the low-grade appearance of the Brevard Zone rocks is due to retrogressive metamorphism. Relict staurolite, kyanite, and sillimanite have been found in the low-grade-appearing rocks virtually throughout the length of the Brevard Zone, from Alabama to northern North Carolina (Keith, 1905, p. 8; Reed and Bryant, 1964, p. 1181, 1183; Butler and Dunn, 1968, p. 43;

Bentley and Neathery, 1970, p. 23-24; Hurst, 1970, p. 389; Roper and Dunn, 1971, 1973; Crawford and Medlin, 1973, p. 714, 719, 1974, p. 1-4; Medlin and Crawford, 1973, p. 99; Roper and Justus, 1973, p. 115).

In Georgia and Alabama rocks in the Brevard Zone are identifiable as belonging to several different thrust sheets in the Georgiabama thrust stack. Near Atlanta, Georgia (figs. 1 and 3), the rocks in the Brevard are retrograded (locally graphitic) schists and phyllonites that are devoid of volcanogenic components and belong to the Bill Arp thrust sheet. Just southwest of Atlanta, these rocks are structurally overlain by the Zebulon thrust sheet and the shearing and retrogression typical of the zone have affected schists, amphibolites, and gneisses of the Zebulon Formation in the Zebulon thrust sheet. A short distance farther to the southwest, the Zebulon sheet in the Brevard Zone is structurally overlain by the Sandy Springs thrust sheet and locally by slices of the Paulding thrust sheet, so that the shearing and retrogression have affected rocks of the Sandy Springs Group and locally the Paulding Volcanic-Plutonic Complex. The shearing and retrogressive effects appear to stay within the Sandy Springs Group and the part of the Jacksons Gap Group (Bentley and Neathery, 1970) that belongs to the Sandy Springs thrust sheet all the way to the Coastal Plain overlap in Alabama (fig. 1). Northeast of Atlanta, the Brevard is mostly composed of rocks of the Bill Arp and Zebulon thrust sheets so closely folded together that we have not yet been able to divide them. Locally rocks of the Sandy Springs sheet occur in the zone northeast of Atlanta.

The marbles in the Brevard Zone have most recently been considered to be Valley and Ridge carbonate shelf sequence rocks (Shady Dolomite or Knox Group rocks) brought to the level of the present surface by thrust faulting (Hatcher, 1971; Hatcher and others, 1973; Hatcher, 1978). Where we have seen these marbles they are always infolded with sequences of sheared pelitic rocks and sheared metagraywacke that lack amphibolites, and appear to belong to the Bill Arp thrust sheet. We interpret the Brevard Zone metacarbonate rocks as representing the same depositional environments as the Murphy and Chewacla Marbles, though probably in a different Ocoee basin. Thus, the Brevard marbles may be roughly the same age as Valley and Ridge carbonate shelf sequence rocks, but they are probably not directly correlative with any of the carbonate shelf sequence units.

Our work has also demonstrated approximately 35 kilometers of late right-lateral displacement along the Brevard Zone between Gainesville, Georgia, and Suwanee, Georgia (fig. 1). Tightly folded stratigraphic sequences of Sandy Springs Group rocks in the Sandy Springs thrust sheet are present on both sides of the Brevard Zone in this stretch between Gainesville and Suwanee, as first suggested by Hurst (1973) and later shown by the detailed work of Kline (1980, 1981). In the vicinity of Gainesville, narrow, parallel, tight to isoclinal, northeast-trending anticlines and synclines, involving the distinctive Sandy Springs stratigraphic sequence, which can be followed for many kilometers to the southwest, bend abruptly southeastward and terminate within (probably structurally above) a narrow outcrop belt of Bill Arp thrust sheet rocks that mark the center of the sheared and retrograded Brevard Zone there. Identical tight folds of the Sandy Springs Group on the southeast side of the Brevard trend southwest to the vicinity of Suwanee and then bend abruptly northwestward to terminate within the Brevard. The bending of the folds and the stratigraphic sequence on both sides of the Brevard Zone are interpreted to be the result of drag folding caused by right-lateral strike-slip faulting along an unseen fault or faults within the narrow zone. The measured displacement is approximately 35 kilometers. Because the offset and drag affect the folds in the Sandy Springs thrust sheet, and because these folds probably formed after the Early Devonian (see above), strike-slip faulting is considered post-Early Devonian. Right-lateral faulting along the Brevard is also suggested by the northeast-trending "tails" of the Carboniferous Ben Hill and Palmetto Granites near

Atlanta (figs. 1 and 3), but no offset of stratigraphic sequences or other features has been found anywhere but in the stretch between Gainesville and Suwanee. The strike-slip faulting along the Brevard is probably post-Carboniferous and local.

There is also evidence of late normal faulting along part of the northwestern border of the Brevard Zone (White, 1950; Butler and Dunn, 1968; Roper and Dunn, 1971; Stonebraker and Harker, 1973; Roper and Justus, 1973), in which the southeastern side is downthrown relative to the northwestern side. Like the strike-slip faulting, this normal faulting is probably post-Carboniferous.

Our interpretation of the pre-Carboniferous Brevard in Georgia and Alabama is akin to the interpretation of Roper and Justus (1973), but with some modifications. We suggest that the Brevard is a complex polytectonic zone of extreme flattening, isoclinal to elasticus folding, and shearing that formed continuously in parts of the thrust sheets beneath and in front of the advancing Clairmont and higher sheets in the Georgiabama thrust stack, and that it was transported cratonward along with the stack. It probably started forming far from its present position as the Clairmont thrust sheet moved onto the underlying Zebulon thrust sheet causing isoclinal folding and shearing of the Zebulon sheet and underlying Bill Arp sheet immediately in front of and beneath the leading edge of the Clairmont and the thick stack of sheets above the Clairmont. As the stack of moving thrust sheets continued to advance, rocks in the zone were continuously refolded, flattened, mylonitized, and remylonitized. Isoclinal folds were almost continuously being formed and then sheared out in different parts of the zone (Roper and Justus, 1973), but vestiges of the original stratigraphic sequences survived in many places, especially in upfolded parts of the Bill Arp sheet and in the Sandy Springs, Paulding, Ropes Creek, and Soapstone Ridge thrust sheets which only became involved and infolded in the Brevard Zone after their leading edges had overidden the leading edge of the Atlanta and Promised Land sheets, but while the greater parts of these sheets were still on top of and moving with the Promised Land and lower sheets (fig. 61).

Thus, the Brevard Zone is a kind of suture zone only in the sense that it is the frontal "suture" of the far-travelled, allochthogenetic Clairmont, Wahoo Creek, Atlanta, and Promised Land thrust sheets. It could also be considered a kind of very complicated tectonic melange formed in front of and beneath a thick stack of thrust sheets.

PLUTONISM

Granitic plutonic rocks underlie large areas in the crystalline terrane of Georgia and Alabama (figs. 1 and 3 - all are not shown in fig. 1). At present, the number of radiometrically dated plutons is small, but available radiometric data coupled with geologic data indicate three major groups of granitic plutons (fig. 59): (1) Cambrian (and Early Ordovician?) plutons that have intruded consanguineous ocean-ridge, ocean-floor, and island arc rocks, and have been transported with these rocks in the Paulding and higher thrust sheets; (2) Silurian-Devonian plutons that have intruded Bill Arp or Bill Arp and Zebulon thrust sheet rocks, but have been overthrust by higher thrust sheets; and (3) Carboniferous plutons that have intruded all of the thrust sheets in the Georgiabama and Little River thrust stacks. The Cambrian plutons appear to have been the result of island arc or ocean-ridge volcanism, whereas the younger plutons appear to have been derived through anatexis of lower thrust sheets (perhaps including Grenville basement in the Bill Arp thrust sheet) in the Georgiabama thrust stack, and of depleted oceanic lithosphere at the base of the Little River thrust stack. The heat necessary to achieve the melting was caused by the blanketing effect of the overlying stack of thrust sheets (see Buck and Toksoz, 1983). Thus, granitic plutonism appears to have taken place when the pile of thrust sheets and stacks was thickest, as from

Silurian through Carboniferous time (fig. 61). Waldbaum (1971) and Wood and Spera (1984) have shown that adiabatic decompression can cause temperature rises in the crust, and Sinha and others (1985) suggest that such decompression may result from isostatic adjustment following loading by the thrust stacks. They (Sinha and others, 1985) suggest that granitic magmas are produced through anatectic melting caused by this decompression, and that the melting takes place about 30-50 m.y. following the extreme stackup of thrust sheets. We believe magma production is more continuous than periodic, but that the stackup of thrust sheets and thrust stacks causes the plutonism, probably by a combination of their blanketing effects (Buck and Toksoz, 1983) and the effects of decompression (Waldbaum, 1971; Wood and Spera, 1984; Sinha and others, 1985); this also applies to the ~400 m.y. old mafic plutons in the Macon melange.

Cambrian (and Ordovician?) plutons

The older group of deformed and metamorphosed pre-Carboniferous granitic plutons in the southern Appalachians are K-feldspar-poor granitic plutons that have intruded the Ropes Creek Metabasalt in the Ropes Creek thrust sheet. Similar plutons are part of the Paulding Volcanic-Plutonic Complex in the Paulding thrust sheet (figs. 1 and 3). Field relations indicate that these plutons have been transported with the thrust sheets and are locally truncated against the basal thrust faults. Therefore, their minimum age based on geologic relations and sparse geochronologic data is Middle Ordovician, but their actual age is probably Cambrian. Some of the plutons, such as the Villa Rica Gneiss in western Georgia (Appendix A), are trondhjemitic (Pate, 1980; Sanders, 1983). Abrams and McConnell (1981) and McConnell and Abrams (1984) considered the Villa Rica Gneiss to be of volcanic origin and called it a "metadacite." However, the Villa Rica is mostly massive and xenoliths of Ropes Creek Metabasalt are common in the gneiss indicating a plutonic origin, as recognized by Pate (1980). The mineralogic and chemical composition of the Villa Rica (Pate, 1980; Sanders, 1983) is similar to some of the thin felsic laminae in the Ropes Creek Metabasalt. The K-feldspar-poor plutons are considered essentially consanguineous with the metavolcanic rocks they have intruded, and most (including the Villa Rica Gneiss) are probably hypabyssal plutons.

Silurian-Devonian plutons

The Austell Gneiss serves as an example of a second group of metamorphosed and deformed plutons. The northeastern "nose" of the Austell-Frolona anticlinorium (fig. 3) is occupied by a coarsely porphyritic or blastoporphyritic biotite-oligoclase-quartz-microcline quartz monzonite gneiss (Coleman and others, 1973; Crawford and Medlin, 1974; Abrams and McConnell, 1981) that Hayes (1901) named the Austell Granite and Medlin and Crawford (1973) renamed the Austell Gneiss. The gneiss is at best only a semiconcordant intrusion whose original shape has been considerably modified especially along its southeast side by thrusting on the Chattahoochee fault (Hurst, 1973)* and along parts of its northwest side by the Sandy Springs and Ropes Creek thrust faults. The Austell has intruded the Bill Arp Formation, of which it contains xenoliths (fig. 60), and is interpreted to have intruded the Zebulon Formation because coarse micas have grown across the foliation

* McConnell and Abrams (1984) and Abrams and McConnell (1984) called that part of Hurst's (1973) Chattahoochee fault lying southeast of the Austell Gneiss and the Austell-Frolona anticlinorium the "Blairs Bridge fault." Our mapping indicates that there is no fault at Blairs Bridge -- Chattahoochee Palisades Quartzite on the northwest limb of a major isoclinal fold crosses Sweetwater Creek uninterrupted within a few tens of meters of Blairs Bridge. The Chattahoochee fault is a valid fault. We recommend abandonment of the name Blairs Bridge fault.

in Zebulon schists near their contact with the gneiss. The Austell Gneiss has been overthrust by the Sandy Springs and higher thrust sheets, which are also folded with the gneiss.

Our mapping shows that the Bill Arp Formation in the northeastern part of the Austell-Frolona anticlinorium has abundant graded beds that indicate clearly that it is in an anticlinorium and that the axial trace of the anticlinorium is truncated at an angle by the Austell Gneiss (fig. 5). Nevertheless, despite the discordancy between the gneiss and the Bill Arp Formation, there are indications that the gneiss has been folded.

Medlin and Crawford (1973; Crawford and Medlin, 1974) mapped a narrow outcrop belt of schist (which they called the Union Grove schist) that forms a fold-like curved pattern within the Austell Gneiss. Abrams and McConnell (1981) recognized that this unit, which also has metagraywacke in it, belongs to the Bill Arp Formation, but they mapped it as truncated against the Chattahoochee fault along the southeast side of the Austell-Frolona fold. Our mapping shows that this thin band of Bill Arp rocks does not truncate against the Chattahoochee fault, but continues southwestward separating the Austell Gneiss, and connects with the main body of the Bill Arp in the anticlinorium, making it even more perplexing. This narrow belt of Bill Arp rocks is a puzzle in any structural interpretation of the Austell Gneiss; it must either be an infolded roof-pendant or a thin septum separating two intrusive masses of the Austell.

Structural features within the Austell Gneiss also indicate that it has been folded. As previous workers have noted, the gneiss has a weak t. moderately well developed foliation formed by alignment of microcline phenocrysts and biotite that appears to conform with its lunate shape. Is this foliation the result of folding under metamorphic conditions, or is it an igneous flow-foliation formed during intrusion of the gneiss? Our study indicates that it is a combination of the two, and that the Austell Gneiss was probably intruded after the Austell-Frolona fold had begun to grow, but before its formation was complete, thereby explaining the discordance between the gneiss and the Bill Arp Formation. The Sandy Springs and higher thrust sheets in the Georgiabama stack were then thrust upon the Austell Gneiss and the Bill Arp and Zebulon thrust sheets and subsequently folded with the gneiss and these thrust sheets as the anticlinorium continued to grow. We suggest that the Austell obtained its foliation partly as a result of igneous flowage as it was emplaced semiconcordantly into the Austell-Frolona anticlinorium, molding itself around the growing fold, and partly as a result of being folded under metamorphic conditions as the anticlinorium continued forming. Its lunate shape is deceiving, because it is the result not of refolding, but of being overthrust and folded with the sheets below and above it and further modified by faulting along its southeast side.

Carboniferous plutons

The youngest group of granitic plutons in the southernmost Appalachians are Carboniferous-Permian (based on radiometric age dates), with age dates ranging from about 350 m.y. to about 260 m.y. (Fullagar and Butler, 1979; Sinha and Zietz, 1982, and references therein), but clustering around 300-320 m.y. (more likely the crystallization age of most of the plutons). Those that have intruded the Little River thrust stack generally have low initial Sr^{87}/Sr^{86} ratios (<0.705) and low δO^{18} ratios (<7.5), whereas those that have intruded the Georgiabama thrust stack have relatively high Sr^{87}/Sr^{86} ratios (>0.706) and relatively high δO^{18} ratios (>7.5) (Sinha and Zietz, 1982, and references therein). Based on field-evidence, some of the Carboniferous plutons that have intruded the Georgiabama thrust stack appear to be relatively thin, shallow-bottomed bodies that were emplaced during folding (for example, Grant and others, 1980). In contrast, many of the

Carboniferous granite plutons that have intruded the Little River allochthon appear to be stock-like bodies (for example, Vincent, 1984) that may extend to relatively great depths. We interpret the Carboniferous plutons that have intruded the Georgiabama thrust stack to have been derived through anatexis of supracrustal rocks in the stack, and the Carboniferous plutons that have intruded the Little River thrust stack to have been derived through partial melting of depleated, metamorphosed Iapetus Ocean crust and mantle entrapped beneath the Little River stack and welded to its base. Some plutons near the thrust boundary between the Georgiabama and Little River thrust stacks, such as the Elberton Granite in eastern Georgia (Whitney and Hess, 1978; Wenner, 1978; Whitney and Stormer, 1980), appear to be gradational between the two groups.

EVOLUTION OF THE SOUTHERNMOST APPALACHIANS

The stacking order of the thrust sheets in the southernmost Appalachians (fig. 2) combined with paleogeographic (paleotectonic) interpretations and facies interpretations (table 3-5; fig. 61) indicate that the farthest-travelled thrust sheets and slices are on top and the least-travelled sheets and slices are on bottom, and that the stacking took place from oceanward toward the North American craton. In the interpretative reconstructions it is assumed that: (1) thick accumulations of island arc-related volcanic rocks require the existence of a subduction zone, regardless of the polarity of that zone; and (2) that the reverse is also true, that the existence of a subduction zone causes plutonism and volcanism in the overriding plate.

Phase I: Opening of the Iapetus Ocean

The earliest record in the southern Appalachians of the opening of the Iapetus Ocean is the thick pile (~3000 m) of metamorphosed interbedded and interfingering basaltic and rhyolitic, peralkaline volcanic and immature clastic sedimentary rocks of the Mount Rogers Formation which nonconformably overlie Grenville basement around the common corner of Virginia, North Carolina, and Tennessee (Rankin, 1975), the correlative but thicker (3,000-9,000 m) Grandfather Mountain Formation, exposed only in the Grandfather Mountain window about 50 kilometers to the south in North Carolina (Bryant and Reed, 1970; Rankin, 1970, 1975, 1976), and the igneous rocks associated with massive sulfide deposits in the lowermost part of the Great Smoky Group on the western flanks of the Murphy syncline in northern Georgia and in the Copperhill and Ducktown areas, Tennessee (Hurst, 1955; Slater, 1985; Slater and others, 1985; Abrams, 1985). There is evidence that Mount Rogers and Grandfather Mountain sequences were erupted and deposited mostly subaerially (Bryant and Reed, 1970; Rankin, 1970), and probably resulted from rifting associated with the beginning phases of the opening of the Iapetus Ocean (Rankin, 1975, 1976; Rodgers, 1982). We suggest that the metavolcanic, metavolcaniclastic, metavolcanic-epiclastic, and hypabyssal intrusive rocks of the Ducktown assemblage (this paper) also resulted from rifting associated with opening of the Iapetus Ocean (also see Slater and others, 1985). Correlative rocks elsewhere in the southern Appalachians may be covered by the crystalline thrust sheets.

The age of the metavolcanic rocks of the Mount Rogers and Grandfather Mountain Formations has been the subject of some dispute (Rankin and others, 1969; Odom and Fullagar, 1971), but as Odom and Fullagar (1973, p. 143) pointed out, the radiometric data "do indicate an age of roughly 850 to 700 m.y." (a span of time greater than the entire Cenozoic). Thus it seems safe to say that the Iapetus Ocean was opening by about 700 m.y. ago, and that by that time the oceanward edge of the North American continent was a trailing edge; spreading was probably taking place along a mid-Iapetus ridge, and the absence of preserved island arc-related volcanic rocks of this age in the southernmost Appalachians suggests a lack of arcs or subduction zones in the Iapetus Ocean near North America (fig. 61a).

After eruption and deposition of the Mount Rogers and Grandfather Mountain Formations and the Ducktown assemblage, continued rifting at the continental edge produced a series of stepped fault-bounded depositional basins along the North American side of the Iapetus Ocean that were filled first by turbidic flysch deposits in enormous coalescing fans. The sedimentary sequences in these basins record the same general depositional environments throughout, even though the preserved "units" may not have been directly "correlative" in age or in continuity; presumably the basins nearest the opening ocean formed and filled first, but we don't know how many Ocoee basins lie buried beneath the thrust stacks.

Generally considered one of the largest and deepest of the basins was the "Ocoee basin" (King and others, 1958), filled with as much as 12 kilometers of poorly sorted, mostly turbidic, clastic metasedimentary rocks of the upper Precambrian Ocoee Supergroup (Hurst, 1955; King and others, 1958; Hadley, 1970; Rogers, 1972; Rankin, 1975). However, even this sequence of rocks appears to have been deposited in more than one basin (also see Bolton, 1985). In northern Georgia, the Ellijay Group probably represents a different, more oceanward basin from the underlying Great Smoky Group, and in North Carolina and Tennessee, King and others (1958, 1960) divided the Ocoee Supergroup rocks into two separate sequences, one north of and below the Greenbriar fault and another south of and above the fault. These two sequences were probably deposited in separate but approximately coeval basins, and if the Ellijay Group there was deposited in still another basin, then at least three separate basins may be represented in these sequences. The lack of volcanogenic material in all but the lowermost parts of this thick pile of metasedimentary rocks (and these probably only around the basin-edge rift systems) suggests that at least the North Americanward side of the growing Iapetus Ocean lacked volcanic island arcs and accompanying subduction zones during the time of Ocoee sedimentation (fig. 61a). We don't know exactly when Ocoee sedimentation began or ended during the late Precambrian, but at least the side of the basin(s) nearest the North American craton had nearly filled by earliest Cambrian time because more mature and proximal (to the shelf or craton) sediments of very latest Precambrian and earliest Cambrian age (upper parts of Great Smoky Group and Chilhowee Group) were deposited at the top of the thick pile of poorly sorted and turbidic sediments. The youngest of the capping sediments (upper Chilhowee Group) were beach-barrier island deposits derived from the craton (Brown, 1970; Whisonant, 1970, 1974; Mack, 1980).

In Georgia and Alabama the Chilhowee Group is without volcanogenic components, but in northeastern Tennessee and southwestern Virginia amygdaloidal basalt flows are present in the lower part (Unicoi Formation) of the group (Rodgers, 1953; Stose and Stose, 1957; Dietrich, 1959; King and Ferguson, 1960; Rankin, 1975, 1976). The fact that these basalts are amygdaloidal flows (Rankin, 1976, p. 5612) and are interbedded with coarse clastic sedimentary rocks (King and Ferguson, 1960) suggests that they are genetically related to extension associated with continued opening of the Iapetus Ocean

By Early Cambrian time the waters of the Iapetus Ocean had begun to encroach upon the North American craton, and by Late Cambrian time much of the craton was covered by a warm shallow sea (see Rodgers, 1968, 1982). Clastic sedimentation had largely ceased by the Middle Cambrian because the cratonic source area had been eroded down or (and) transgressed by the sea, and the Cambrian-Ordovician carbonate shelf sequence, consisting of about 1,500-2,900 meters of shallow-water carbonate rocks (Rodgers, 1968, and references therein; Cressler, 1970; Thomas and Neathery, 1980), was deposited upon the slowly subsiding North American continental margin (fig. 61b).

With the exception of a few thin "bentonite" beds in the Middle Ordovician part of the sequence (Butts, 1926; Butts and Gildersleeve, 1948; Allen and Lester,

1957; Cressler, 1970; Smith and others, 1971; Chowns and Carter, 1983), which are generally regarded as derived from volcanic ash, the Cambrian-Ordovician carbonate shelf sequence is without volcanogenic components.

Thus it appears that from the time of eruption of the Mount Rogers and Grandfather Mountain Formations, at least 700 m.y. ago (and more likely earlier), through the Early Ordovician, the eastern margin of the North American continent was too far from any volcanic source to receive volcanogenic material.

Phase II: Closing of the Iapetus Ocean - The Iapetan Orogeny

Closing of the Iapetus Ocean must have begun with the establishment of one or more subduction zones (fig. 61c). One of these paleosubduction zones must have been located beneath the thick sequences of island arc metavolcanic rocks preserved in the Little River allochthon; its subduction melange is preserved as the Macon melange. All available evidence suggests that the Little River volcanic arc formed at the edge of a continental mass, and the presence of Atlantic realm trilobites in some of its rocks (Secor and others, 1983) indicates that the continent was not North America - for the purposes of this paper we will refer to it as "Africa," even though it may not have been the continental mass of present Africa. The age of the rocks preserved in the Little River allochthon probably span from very latest Precambrian (latest Proterozoic) through Middle Cambrian, indicating that at least by about 600 m.y. ago (depending on whether the lower parts of the arc volcanics are preserved) the arc and subduction zone were active.

Island arc volcanism and subduction in the Iapetus Ocean are also recorded by the metavolcanic rocks preserved in the Wahoo Creek, Atlanta, and Promised Land thrust sheets, and to a lesser extent by the rocks in the Sandy Springs thrust sheet. We call this island arc the Promised Land arc. Zircons with radiometric ages over a billion years in Chattahoochee Palisades Quartzite of the Sandy Springs Group (T.W. Stern, oral commun., 1984) indicate that the Promised Land arc was built on old Grenville-age continental crust in a Sandy Springs microcontinent.

A third island arc, the Paulding arc, is represented by the Paulding Volcanic-Plutonic Complex in the Paulding thrust sheet. The abundance of felsic volcanic and volcaniclastic rocks and the presence of K-feldspar-poor plutonic rocks in the Paulding sequences suggest island arc volcanism, as does the geochemical character of the rocks in the Paulding thrust sheet (Tull and others, 1978; Tull and Stow, 1980a, 1980b; Stow, 1982; Stow and others, 1984; Appendix B). Lack of nonvolcanogenic metasedimentary rocks in this complex suggests that the Paulding was an oceanic arc. The Clairmont melange is interpreted to be the preserved remnants of the subduction melange associated with Promised Land arc volcanism. The subduction zone probably dipped away from the North American continent (fig. 61). Sparse chronologic data suggest that the metavolcanic rocks in the Paulding thrust sheet are probably mostly older than about Middle Ordovician (Russell and others, 1984), and hence about the same age as much of the metavolcanic sequence in the Little River allochthon.

Establishment of subduction zones beneath the Little River, Promised Land, and Paulding island arcs marked the beginning of the end of the Iapeus Ocean, even though the effects of plate collision would not be recorded in rocks associated with the continental margin of North America for many millions of years. Opening of the Iapetus Ocean began at least 700 m.y. ago (the minimum age of the Mount Rogers and Grandfather Mountain Formations) and lasted until subduction zones were established beneath the Paulding and Little River arcs during the latest Precambrian, perhaps roughly 600 m.y. ago. Neither age is well established, but the suggestion is that opening of the ocean took at least 100 m.y. Assuming a reasonable average spreading rate along the mid-Iapetos ridge (both sides) of 5

cm/year (Windley, 1976, p. 233; the TiO_2 contents of Ropes Creek Metabasalt suggest about this rate of spreading or more) gives a minimum width of 5,000 kilometers for the ocean at the time of its greatest width just before the subduction zones were established. If the U-Pb ages of zircons (~820 m.y.) from the Mount Rogers and Grandfather Mountain Formations (Rankin and others, 1969) are closer to the real age of the rocks (as they probably are) than the Rb-Sr whole-rock ages (~686 m.y.) from plutonic rocks thought to be the same age as the volcanic rocks (Odom and Fullagar, 1971), if the basalts within the Unicoi Formation originated through rifting associated with continued opening of the Iapetus Ocean (as they probably did), or if the average spreading rate along the mid-Iapetus ridge was greater than 5 cm/year, then the width of the Iapetus Ocean may have been far greater than 10,000 kilometers.

Location of the Little River arc seems relatively well-fixed. All available data indicate that this arc was located at the oceanward edge of the "African" continent and that the subduction zone beneath its Macon subduction melange dipped toward that continent (fig. 61b and c). However, there is little firm evidence to indicate either the paleolocation of the Paulding arc or the polarity of its subduction zone. Nevertheless, the stacking order within the Georgiabama thrust stack places some limitations on reconstructions of the paleogeography. If the ultramafic and mafic assemblages of the Soapstone Ridge thrust sheet are altered fragments of Iapetus Ocean crust and mantle (disrupted ophiolite), as all of the evidence indicates, and if their structural position, always at the top of the Georgiabama thrust stack, indicates thay they are the most oceanward rocks preserved in the stack, as all of the evidence suggests, then they must have originally resided oceanward from the underlying Ropes Creek, West Point, Paulding, Sandy Springs, Promised Land, Atlanta, Wahoo Creek, and Clairmont thrust sheet rocks. Abundant evidence indicates that the rocks in the Ropes Creek thrust sheet are Iapetus Ocean crust, and its place structurally beneath the Soapstone Ridge sheet indicates that it also resided oceanward from the underlying thrust sheets. The Paulding island arc must therefore have been located toward the North American continent from the Ropes Creek Metabasalt. The position of the ophiolitic, eclogite-bearing West Point subduction melange structurally beneath the Ropes Creek thrust sheet and above the Paulding thrust sheet indicates that the subduction zone associated with the Paulding arc dipped toward the North American continent (fig. 61b-d). The lack of nonvolcanogenic metasedimentary rocks in the Paulding thrust sheet suggests that the Paulding arc was an oceanic arc rather than being associated with the edge of the North American continent or some microcontinent, as does the predominately mafic nature of its West Point subduction melange.

The presence of the Sandy Springs thrust sheet beneath the Paulding thrust sheet indicates that its rocks resided continentward from the Paulding island arc (fig. 61b-d). Grenville-age detrital zircons in the Chattahoochee Palisades Quartzite of the Sandy Springs Group indicate that Grenville-age basement contributed to the sedimentary protoliths of the Sandy Springs rocks. This suggests that they formed in a different arc from the oceanic Paulding arc. However, thin amphibolites in the Sandy Springs units are probably metabasaltic tuffs, indicating volcanic input into the sedimentary protoliths. Moreover, the Sandy Springs thrust sheet is underlain by the totally igneous (mostly volcanic) Promised Land thrust sheet which has characteristics of an island arc assemblage. The Promised Land is structurally underlain by sequences interpreted to be outer-arc basin deposits in the Atlanta thrust sheet, which are in turn underlain by what appear to be altered volcaniclastic deposits and granitic rocks in the Wahoo Creek thrust sheet. The Wahoo Creek is structurally underlain by the Clairmont melange. The most reasonable paleogeographic reconstruction is that the Paulding arc was located separate from the sequences in the underlying thrust sheets, and that rocks in these

underlying sheets formed in a different Promised Land island arc built upon Grenville-age continental crust (Sandy Springs microcontinent) that was rifted away from the North American continent when the Iapetus Ocean opened (fig. 61a-d). We interpret the Clairmont melange as the remnant of the subduction melange associated with the subduction zone that caused the arc volcanism in the Promised Land arc, and because of its structural position beneath the outer-arc basin and island arc rocks of the Wahoo Creek, Atlanta, and Promised Land sheets, we suggest that this subduction zone dipped away from the North American continent.

The lack of volcanogenic rocks younger than Middle Cambrian in the Little River allochthon suggests that subduction under the Little River arc had ceased by Late Cambrian time. We offer the speculation that the Little River arc and Macon melange, at the oceanward edge of the "African" continent, overrode the mid-Iapetus ridge during the Late Cambrian (fig. 61d), thereby stopping subduction under the arc, just as the collision of the North American plate with the East Pacific Rise has stopped subduction along part of the west coast of North America. This would have had the net effect of speeding up movement of the Little River arc toward the North American continent and would also have speeded up subduction under the Paulding arc until oceanic crust could no longer be consumed fast enough, so it buckled and broke.

We suggest that collision began with obduction of Soapstone Ridge oceanic crust and mantle onto Ropes Creek oceanic crust (fig. 61d), and obduction of the Ropes Creek Metabasalt onto the West Point melange and Paulding island arc rocks (fig. 61e). This would have stopped subduction under the Paulding arc and also would have terminated volcanism and plutonism in the arc. Unfortunately, the upper age of the metavolcanic rocks in the Paulding thrust sheet is unknown, but based on discordant dates of zircons from felsic rocks within the Paulding part of the Hillabee greenstone (see above) could be as young as Ordovician. Continued assembly of thrust sheets involved rocks of the Promised Land arc, where subduction probably ceased when the Clairmont melange and the arc overrode the spreading center (fig. 61c). These Promised Land arc rocks were then thrust upon Zebulon ocean floor deposits (fig. 61f). At any rate, we suggest that the Ocean-to-continentward (top to bottom) assembly of the Georgiabama thrust stack was nearly complete by the Middle Ordovician, and that as the Clairmont thrust sheet and the overlying stack moved onto the Zebulon sheet and it in turn onto the Bill Arp thrust sheet the earliest response was buckling up of the carbonate shelf at the oceanward edge of the North American craton, causing erosion that resulted in the unconformities at the top of the Upper Cambrian-Lower Ordovician Knox Group, and later above the Middle Ordovician Lenoir Limestone - the shelf was literally bobbing up and down in response to the arriving thrust sheets (fig. 61f). With continued movement, the cratonward edge of the Bill Arp sheet was thrust up along with part of the carbonate shelf above it and oceanward equivalents of the Rockmart Slate and Athens Shale below it to cause a landmass that separated the Rockmart-Athens-Talladega basin from what was left of the Iapetus Ocean (fig. 61g). Dark, calcareous, graptolitic pelites were first deposited in this basin. Erosion of carbonate shelf sequence and Bill Arp thrust sheet rocks supplied clastic material to the basin in the form of a clastic wedge (Tellico-Talladega clastic wedge), and continued movement locally at least pushed parts of the dark pelite sequences (Rockmart, Athens, Talladega) up the paleoslope onto the unconformity at the top of the carbonate shelf, folding and mildly metamorphosing the pelites in the process. Continued movement and erosion of the thrust-up Bill Arp sheet rocks caused deposition and cratonward transgression (the source was also moving toward the craton) of a molasse-like clastic wedge composed of the Greensport, Colvin Mountain, and Sequatchee Formations (figs. 61h and 61i), and atop these the Silurian Red Mountain Formation (fig. 61j). Further cratonward movement of the Clairmont melange and

higher thrust sheets in the Georgiabama thrust stack probably loaded the underlying Zebulon and Bill Arp sheets and thereby the oceanward edge of what was left of the carbonate shelf allowing deposition of the thin Lower and Middle Devonian Armuchee Chert-Frog Mountain Sandstone (including Jemison Chert-Butting Ram Sandstone) sequence (fig. 61k). By the late Middle Devonian or Late Devonian the Paulding, West Point, and Ropes Creek thrust sheets had locally transgressed far enough towards the craton to be emplaced upon the Lower and Middle Devonian craton-related Jemison Chert-Butting Ram Sandstone sequence (fig. 61l). Cratonward movement of the Georgiabama thrust stack continued, and collision finally shoved the remnants of the Macon subduction melange wedge, the Little River island arc, preserved in the Little River allochthon, and back-arc basin deposits, preserved as the Northern Florida platform sequence now beneath the Coastal Plain in southern Georgia and northern Florida, onto the top of the Georgiabama thrust stack (fig. 61m). Oceanic crust and mantle entrapped beneath the Macon melange and Little River allochthon is probably the cause of the major gravity gradient that crosses Georgia, and Alabama (American Geophysical Union, 1964; Long and others, 1972). Partial melting of the entrapped oceanic material (by now welded onto the bottom of the thrust stack and metamorphosed and depleated) probably accounts for low initial Sr^{87}/Sr^{86} ratios and low δO^{18} ratios (Sinha and Zietz, 1982, and references therein) of Carboniferous granitic rocks that have intruded the Macon melange and Little River allochthon. Such granites appear to be confined to the outcrop area of the Macon melange and Little River allochthon. Final cratonward movement of the whole assembled set of thrust stacks took place along the Emerson, Talladega, Carters Dam, Rome and Helena, Clinchport, and Kingston faults during the late Carboniferous (fig. 61n) and Permian(?).

COMPARISON WITH THE NORTHERN APPALACHIANS

There are obvious similarities between the stacking order and sequence of events depicted above for the southernmost part of the Appalachian orogen and the stacking order and sequence of events in the northern Appalachians, but there are also significant differences, especially in the size and travel distances of the thrust sheets and in the timing of events. In the northern Appalachians (Bird and Dewey, 1970; Williams and others, 1972; St. Julien and Hubert, 1975; Williams, 1975, 1979; Rowley and Kidd, 1981) the major transported terranes are on the order of 50 kilometers wide, some of the ophiolites are complete ophiolite suites (Upadhyay and others, 1971; Williams and Smyth, 1973) with basal metamorphic aureoles interpreted to be the result of obduction and initial transport of hot oceanic crust and mantle (Williams and Smyth, 1973), the ophiolites are at the top of the structural stack and have (Williams, 1975, p. 1876) "transgressed locally farthest west to lie upon autochthonous rocks," and they are the farthest-travelled slices with minimum transport distances of 80-105 kilometers (Williams and Smyth, 1973). Many of the thrust slices (sheets) in the stack are separated by melanges that have sedimented detritus from higher slices, including detritus from the ophiolite slices (Stevens, 1970; Stevens and Williams, 1973; Williams and Smyth, 1973). In addition, the time of original displacement of the ophiolite slices in the Canadian Appalachians is dated as Early Ordovician by the age of their metamorphic aureoles and by the presence of ophiolite detritus in underlying slices of Lower Ordovician clastic sedimentary rocks, and their time of final emplacement is well-dated as Middle Ordovician by overlying neoautochthonous, fossiliferous Middle Ordovician sedimentary rocks (Bergstrom and others, 1974). Accretion of the thrust stack apparently occurred slightly later in New England than in Canada (Bird and Dewey, 1970). Throughout much of the northern Appalachians there is a relatively wide "foreland" at the western edge of the orogen where autochthonous and parautochthonous Middle Ordovician metasedimentary rocks are overlain by stacked

sequences of allochthonous metasedimentary rocks of about the same age (Zen, 1967; Stevens, 1970; Rodgers, 1970; St. Julien and Hubert, 1975; Rowley and Kidd, 1981).

In the southernmost Appalachians most individual thrust sheets appear to have been a minimum of 160 kilometers wide, the ophiolites are altered, dismembered, and generally incomplete, and as far as we know they lack basal metamorphic aureoles. In the southernmost Appalachians ophiolite occurs in three ways: (1) as sheets (Soapstone Ridge and Ropes Creek thrust sheets) that were obducted and thrust cratonward at the top of an enormous (Georgiabama) thrust stack; (2) as debris shed from the ophiolitic thrust sheets and deposited in protoliths of underlying thrust sheets in the stack during assembly of the stack; and (3) as clasts of all sizes incorporated into subduction melanges (Clairmont, West Point, and Macon melanges). As in the northern Appalachians, the obducted ophiolite sheets are the farthest-travelled (excluding rocks in the Little River thrust stack), and have transgressed farthest toward the craton; minimum transport distances must exceed 160 kilometers, and are probably more on the order of thousands of kilometers. In contrast with the northern Appalachians, many of the thrust sheets in the Georgiabama thrust stack are not separated by melange but by what appear to have been "hard" thrusts; major melanges appear to separate sequences of thrust sheets whose rocks formed in different tectonic settings such as different island arcs, and most of these melanges have characteristics indicating that they are the preserved remnants of subduction melange complexes. The time of original displacement of the obducted ophiolite sheets in the southernmost Appalachians is not as well known as in the northern Appalachians, but was probably Late Cambrian-Early Ordovician, whereas the time of final emplacement of these sheets (excluding transport of the whole stack along late Paleozoic thrust faults) and underlying (West Point melange and Paulding) subduction melange and island arc rocks was clearly post-early Middle Devonian because they rest in thrust contact upon fossiliferous Lower and Middle Devonian Valley and Ridge province cherts. Also in contrast with the northern Appalachians, much of the "foreland" in the southernmost Appalachians has been covered by the thrust stack being transported along late Paleozoic thrust faults, so that only the thin cratonward edges of Middle Ordovician dark graptolitic pelites are found resting upon carbonate shelf rocks.

In the southernmost Appalachians, remnants of a large subduction melange, the Macon melange, comparable in size with the Franciscan melange complex in California, are preserved beneath remnants of the bimodal, calcalkaline "African" continental-margin Little River arc preserved in the Little River allochthon. The metasedimentary and metavolcanic rocks of the "Avalon terrane" in the northern Appalachians may be older equivalents of the Little River allochthon rocks, but less of them is preserved compared with Little River allochthon rocks in the southernmost Appalachians (Williams, 1975; Zen, 1983). Subduction melange, probably older than the Macon melange, is also present in the northern Appalachians, but again, a much thinner outcrop belt is preserved than in the southernmost Appalachians, possibly because much of it in the northern Appalachians was overridden (Zen, 1983, and references therein).

We suggest that many of the geologic differences between the northern and southernmost Appalachians, and the apparently diachronous sequence of thrusting, deformation, and metamorphism (orogeny), may result from the original configuration of the Iapetus Ocean. Bird and Dewey (1970, p. 1049) suggested that the diachronous sequence of deformation between Newfoundland and New England might be explained if:

> "the rate of development of igneous, metamorphic, and structural events ... was in some way proportionally related to the rate of underthrusting. The rate of underthrusting of a spherical shell will increase away from

its rotation pole. If New England were nearer the rotation pole for the contracting Appalachian-Atlantic plate than Newfoundland, the Humberian sequence might be expected to have propagated continentward more rapidly than the Taconian sequence in New England."

We suggest a simplistic model in which the Iapetus Ocean, at the time of beginning of closure, was much narrower at the paleolatitude of Newfoundland than at the paleolatitude of the southernmost Appalachians, so that it closed like a door hinged at the north (present direction), with the effects migrating continuously along the continental margin like a triple-point, causing diachronous orogenic deformation that was progressively older and more telescoped in the northeast and progressively younger, longer lasting, and broader in the southwestern parts of the orogen. Thus the oceanic material was farther travelled from its place of origin (mid-Iapetus ridge), and hence cold when it was obducted in the southernmost Appalachians, thereby accounting for the lack of metamorphic aureoles beneath it. The oceanic material was probably older in the southernmost Appalachians than in the northern Appalachians, but there is, as yet, no evidence of this. The wider part of the ocean would have taken longer to close (slower continentward propogation), and sheets of greater width would have been pushed farther up the paleoslope. Moreover, volcanism associated with subduction would have lasted longer in the southwest than in the northeast, perhaps accounting for southwestward-younging sequences in the "Carolina slate belt" (Samson and others, 1982; Kish and Black, 1982; D.T. Secor, Jr., oral commun., 1982).

In contrast with the drastically telescoped northern Appalachians (Williams, 1979), the southernmost Appalachians (including rocks now beneath the Coastal Plain) contain preserved accreted remnants of sequences of rocks that virtually spanned the Iapetus Ocean from North American craton to African craton, including remnants of clastic sequences formed during the opening rifting phases of the ocean, remnants of island arc assemblages from both sides of the ocean, remnants of subduction melange complexes from both sides of the ocean, and ophiolites from both sides of the mid-Iapetus ridge.

COMPARISON WITH THE INDONESIAN REGION

The Indonesian region, which includes most of the southwestern part of the Pacific Ocean and the southernmost part of the Asian continent, is a complicated collage of small plates each with a different motion, and each interacting in a different way with other small plates and (or) with major plates, and transcurrent movement between plates is relatively common (Hamilton, 1979, and references therein). One can readily surmise, as Hamilton (1979, 307-308) did, that continued movement of the major plates will probably result in the smaller plates (island arcs, microcontinents, etc.) being "squashed between Australia and Asia." If transcurrent movement is relatively common, why then, do we not find evidence of major transcurrent movements in the southernmost Appalachians? The answer is probably a matter of scale. Figure 62 shows the southern Appalachians at the same scale as the Indonesian region, and makes it obvious that the southern part of the Appalachian orogen (in fact the whole Appalachian orogen) is tiny when viewed with the perspective of the Indonesian region. The whole of the southern Appalachian crystalline terrane could be fitted into the island of Sumatra or Java, and the largest melange known in the Appalachians, the Macon melange, is dwarfed by both active and fossil melanges in the Indonesian region. The along-strike continuity of the Macon melange may seem incredible to many Appalachian geologists, but a melange of this size is small by Indonesian standards. The absence of evidence of major transcurrent movement in the southernmost Appalachians (also see Irving and Strong, 1984) can be accounted for if this part of the orogen was more like Sumatra

and Java than, for example like New Guinea or Sulawesi (Hamilton, 1979, Pl. 1). Nevertheless, the southernmost Appalachians do contain remnants of melange complexes and island arcs (such as the West Point melange and Paulding Volcanic-Plutonic Complex) that are probably not present in the central and northern Appalachians, and the central and northern Appalachians probably contain remnants of melange complexes and island arcs (Sykesville melange and Chopawamsic and James Run Formations of the central Appalachians, for example - see Drake and Morgan, 1981; Pavlides, 1981) that aren't present in the southernmost Appalachians. Our reconnaissance suggests that some of the metavolcanic and metavolcanic-epiclastic rocks in southern Virginia (Virgilina area) that have been assigned to the "Carolina slate belt" (Glover and Sinha, 1973; Williams, 1978), probably originated in a different island arc from the Little River Arc. There is also the possibility (A.A. Drake, Jr. and Richard Goldsmith, written communs., April, 1984) that some of the thrust sheets in the Georgiabama thrust stack accreted to lower sheets in a lateral or oblique fashion; this appears to have been the case with higher sheets arriving upon the Zebulon and Bill Arp sheets.

The characteristics of preserved remnants of subduction melange complexes in the southernmost Appalachians match well with those of both active and fossil melanges in the Indonesian region, and with Hamilton's (1979, p. 28-30) model of a subduction melange wedge. The Potato Creek, Juliette, Kings Mountain, and Po Biddy slices of the Macon melange probably represent slightly different tectonostratigraphic (or lithotectonic) facies within the wedge. Sequences with characteristics of outer-arc basin deposits (Atlanta thrust sheet for example) or back-arc basin deposits (Zebulon Formation) fit readily into the Indonesian model, as do island arc deposits (Promised Land Formation, Paulding Volcanic-Plutonic Complex). Despite transport, deformation, and metamorphism, remnants of subduction melange complexes are preserved beneath remnants of each island arc sequence in the southernmost Appalachians (West Point melange/Paulding arc, Clairmont melange/Promised Land arc, Macon melange/Little River arc), and both obducted ophiolite (Soapstone Ridge, Ropes Creek) and ophiolite in melanges (clasts in West Point and Macon melanges) are present.

REFERENCES CITED

Abrams, C.E., 1985, Base metal mines and prospects of Fannin County, Georgia, an extension of the Ducktown trend (abs.): Geological Society of America Abstracts with Programs, v. 17, no. 2, p. 77.

Abrams, C.E., and McConnell, K.I., 1981, Stratigraphy of the area around the Austell-Frolona antiform; west-central Georgia, in Wigley, P.B., ed., Latest thinking on the stratigraphy of selected areas in Georgia: Georgia Geologic Survey Information Circular 54-A, p. 55-67.

Abrams, C.E., and McConnell, K.I., 1982, Banded iron formation: a key marker unit for massive sulfide exploration in the high grade metamorphic terrain of western Georgia (abs.): Geological Society of America Abstracts with Programs, v. 14, nos. 1 and 2, p. 1.

Abrams, C.E., and McConnell, K.I., 1984, Geologic setting of volcanogenic base and precious metal deposits of the west Georgia Piedmont: a multiply deformed metavolcanic terrane: Economic Geology, v. 79, p. 1521-1539.

Absher, B.S., and McSween, H.Y., Jr., 1985, Granulites at Winding Stair Gap, North Carolina: the thermal axis of Paleozoic metamorphism in the southern Appalachians: Geological Society of America Bulletin, v. 96, no. 5, p. 588-599.

Adams, G.I., 1926, The crystalline rocks, in Adams, G.I., and others, The geology of Alabama: Alabama Geological Survey Special Report No. 14, p. 25-40.

Adams, G.I., 1930, The significance of the quartzites of the Pine Mountain in the crystallines of west-central Georgia: Journal of Geology, v. 38, no. 3, p. 271-279.

Adams, G.I., 1933, General geology of the crystalline rocks of Alabama: Journal of Geology, v. 41, p. 159-173.

Alabama Geological Survey, 1926, Geologic map of Alabama: Tuscaloosa, Alabama Geological Survey, scale 1:500,000.

Alabama Geological Survey, 1973, Preliminary geologic map of the crystalline rocks of Alabama: Tuscaloosa, Alabama Geological Survey open-file map, scale 1:250,000.

Allard, G.O., Carpenter, R.H., and Abrams, C.E., 1985, Canadian greenstone belt models -- Do they apply in the southern Appalachians? (abs.): Geological Society of America Abstracts with Programs, v. 17, no. 2, p. 77.

Allen, A.T., and Lester, J.G., 1957, Zonation of the Middle and Upper Ordovician strata in northwestern Georgia: Georgia Geological Survey Bulletin 66, 110 p.

American Commission on Stratigraphic Nomenclature, 1970, Code of stratigraphic nomenclature (2nd edition): American Association of Petroleum Geologists, 45 p.

American Geophysical Union, Special Committee for the Geophysical and Geological Study of the Continents, 1964, Bouguer gravity anomaly map of the United States (exclusive of Alaska and Hawaii): U.S. Geological Survey, 2 sheets, scale 1:2,500,000.

Ando, C.J., Cook, F.A., Oliver, J.E., Brown, L.D., and Kaufman, Sidney, 1983, Crustal geometry of the Appalachian orogen from seismic reflection studies, in Hatcher, R.D., Jr., and others, eds., Contributions to the tectonics and geophysics of mountain chains: Geological Society of America Memoir 158, p. 83-101.

Applin, P.H., 1951, Preliminary report on buried pre-Mesozoic rocks in Florida and adjacent states: U.S. Geological Survey Circular 91, 28 p.

Arden, D.D., Jr., 1974a, A geophysical profile in the Suwannee Basin, north-western Florida, in Stafford, L.P., ed., Symposium on the petroleum geology of the Georgia Coastal Plain: Georgia Geological Survey Bulletin 87, p. 111-122.

Arden, D.D., Jr., 1974b, Geology of the Suwannee Basin interpreted from geophysical profiles: Gulf Coast Association of Geological Societies Transactions, v. 24, p. 223-230.

Atkins, R.L., and Higgins, M.W., 1980, Superimposed folding and its bearing on geologic history of the Atlanta, Georgia, area, in Frey, R.W., ed., Excursions in southeastern geology, v. 1: Washington, D.C., American Geological Institute, p. 19-40.

Bayley, W.S., 1928, Geology of the Tate quadrangle, Georgia: Georgia Geological Survey Bulletin 43, 170 p.

Bell, Henry, III, 1982, Strata-bound sulfide deposits, wall-rock alteration, and associated tin-bearing minerals in the Carolina slate belt, South Carolina and Georgia: Economic Geology, v. 77, p. 294-311.

Bell, Henry, III, Carpenter, R.H., and Feiss, P.G., 1980, Volcanogenic ore deposits of the Carolina slate belt, in Frey, R.W., ed., Excursions in southeastern geology: Washington, D.C., American Geological Institute, p. 149-178.

Bentley, R.D., 1969, Strike slip faults in Lee County, Alabama (abs.): Geological Society of America Abstracts with Programs for 1969, part 4, p. 5.

Bentley, R.D., and Neathery, T.L., 1970, Geology of the Brevard fault zone and related rocks of the inner Piedmont of Alabama: Guidebook, Eighth Annual Field Trip, Alabama Geological Society: Tuscaloosa, Alabama Geological Society, 119 p.

Bentley, R.D., Neathery, T.L., and Scott, J.C., 1982, Geology and mineral resources of Lee County, Alabama: Alabama Geological Survey open-file report, 110 p.

Bergstrom, S.M., 1973, Biostratigraphy and facies relations in the lower Middle Ordovician of easternmost Tennessee: American Journal of Science, v. 273-A, p. 261-293.

Bergstrom, S.M., and Drahovzal, J.A., 1972, Facies relations in the Middle Ordovician of the southern Appalachians in Alabama (abs.): Geological Society of America Abstracts with Programs, v. 4, no. 2, p. 60-61.

Bergstrom, S.M., Riva, John, and Kay, Marshall, 1974, Significance of conodonts, graptolites, and shelly faunas from the Ordovician of western and north-central Newfoundland: Canadian Journal of Earth Sciences, v. 11, p. 1625-1660.

Bird, J.M., and Dewey, J.F., 1970, Lithosphere plate-continental margin tectonics and the evolution of the Appalachian orogen: Geological Society of America Bulletin, v. 81, no. 4, p. 1031-1060.

Bluhm, C.T., and Zimmerman, Jay, Jr., 1977, Structure of the Frank ultramafic tectonite Avery County, North Carolina (abs.): Geological Society of America Abstracts with Programs, v. 9, no. 2, p. 121.

Bolton, J.C., 1985, Tectonically formed basins within the Ocoee Supergroup (abs.): Geological Society of America Abstracts with Programs, v. 17, no. 2, p. 82.

Bosworth, William, and Rowley, D.B., 1984, Early obduction-related deformation features of the Taconic allochthon: Analogy with structures observed in modern trench environments: Geological Society of America Bulletin, v. 95, no. 5, p. 559-567.

Bramlett, K.W., 1980, Geology of the Johnston-Edgefield area, South Carolina, and its regional implications: Columbia, University of South Carolina, unpublished M.S. thesis, 56 p.

Brewer, W.M., 1896, Upper gold belt of Alabama: Alabama Geological Survey Bulletin 5, Part 1, 202 p.

Bridge, Josiah, and Berdan, J.M., 1952, Preliminary correlation of the Paleozoic rocks from test wells in Florida and adjacent parts of Georgia and Alabama: Florida Geological Survey Guidebook, Association of American State Geologists, 44th Annual Meeting Field Trip, p. 29-38.

Brown, L.D., and Oliver, J.E., 1976, Vertical crustal movements from levelling data and their relation to geologic structure in the eastern United States: Reviews of Geophysics and Space Physics, v. 14, no. 1, p. 13-35.

Brown, W.R., 1980, Investigations of the sedimentary record in the Piedmont and Blue Ridge of Virginia, in Fisher, G.W., and others, eds., Studies of Appalachian geology -- central and southern: New York, Interscience Publishers, p. 335-349.

Bryant, Bruce, and Reed, J.C., Jr., 1970a, Geology of the Grandfather Mountain window and vicinity, North Carolina and Tennessee: U.S. Geological Survey Professional Paper 615, 190 p.

Bryant, Bruce, and Reed, J.C., Jr., 1970b, Structural and metamorphic history of the southern Blue Ridge, in Fisher, G.W., and others, eds., Studies of Appalachian geology -- central and southern: New York, Interscience Publishers, p. 213-225.

Bucher, W.H., 1933, The deformation of the Earth's crust: Princeton, New Jersey, Princeton University Press, 518 p.

Buck, W.R., and Toksoz, M.N., 1983, Thermal effects of continental collisions: Thickening a variable viscosity lithosphere: Tectonophysics, v. 100, p. 53-69.

Burchfiel, B.C., and Livingston, J.L., 1967, Brevard zone compared to Alpine root zones: American Journal of Science, v. 265, p. 241-256.

Butler, J.R., 1971, Comparative tectonics of some Alpine and southern Appalachian structures (abs.): Geological Society of America Abstracts with Programs, v. 3, p. 299.

Butler, J.R., 1973, Brevard zone of the southern Appalachians: a review (abs.): Geological Society of America Abstracts with Programs, v. 5, p. 143.

Butler, J.R., 1981, Geology of the Blacksburg South quadrangle, South Carolina, in Horton, J.W., Jr., and others, eds., Geological investigations of the Kings Mountain belt and adjacent areas in the Carolinas: Carolina Geological Society Field Trip Guidebook 1981, p. 65-71.

Butler, J.R., and Dunn, D.E., 1968, Geology of the Sauratown Mountains anticlinorium and vicinity, North Carolina: Southeastern Geology Special Publication 1, p. 19-47.

Butler, J.R., and Fullagar, P.D., 1978, Petrochemical and geochronological studies of plutonic rocks in the southern Appalachians: III. leucocratic adamellites of the Charlotte belt near Salisbury, North Carolina: Geological Society of America Bulletin, v. 89, no. 3, p. 460-466.

Butts, Charles, 1926, The Paleozoic rocks, in Adams, G.I., and others, Geology of Alabama: Alabama Geological Survey Special Report 14, p. 40-223.

Butts, Charles, and Gildersleeve, Benjamin, 1948, Geology and mineral resources of the Paleozoic area in northwest Georgia: Georgia Geological Survey Bulletin 54, 176 p.

Carpenter, R.H., 1971, Norite intrusives in western Jasper County and eastern Monroe County, Georgia, in Georgia Geological Society 6th Annual Field Trip Guidebook: Georgia Geological Survey, p. 1-7.

Carpenter, R.H., and Allard, G.O., 1982, Aluminosilicate assemblages: An exploration tool for metavolcanic terrains (sic) of the southeast, in Exploration for metallic resources in the southeast: Athens, University of Georgia, p.19-22.

Carpenter, R.H., and Hughes, T.C., 1970, A geochemical and geophysical survey of the Gladesville Norite, Jasper County, Georgia: Georgia Geological Survey Information Circular 37, 7 p.

Carpenter, R.H., and Prather, J.P., 1971, A gravity survey of the south-central Georgia Piedmont: Georgia Geological Survey Information Circular 42, 6 p.

Carpenter, R.H., Odom, A.L., and Hartley, M.E., III, 1982, Geochronological investigations of the Lincolnton metadacite, Georgia and South Carolina, in Bearce,

D.M., and others, eds., Tectonic studies in the Talladega and Carolina slate belts, southern Appalachian orogen: Geological Society of America Special Paper 191, p. 145-152.

Carrington, T.J., 1973, Metamorphosed Paleozoic sedimentary rocks in Chilton, Shelby, and Talladega Counties, Alabama, in Carrington, T.J., ed., Talladega metamorphic front: Alabama Geological Society 11th Annual Field Trip, Guidebook, p. 22-38.

Carrington, T.J., and Wigley, P.B., 1967, Redefinition of the Hillabee Schist, Alabama: Southeastern Geology, v. 8, p. 19-31.

Carter, B.D., Chowns, T.M., Crawford, T.J., Grainger, G.S., Rich, Mark, and Waters, J.A., 1983, Geology of Paleozoic rocks in the vicinity of Rome, Georgia, Chowns, T.M., ed.: Field Trip Guidebook, 18th Annual Field Trip, Georgia Geological Society, 92 p.

Cazeau, C.J., 1967, Geology and mineral resources of Oconee County, South Carolina: South Carolina Development Board Division of Geology Bulletin 34, 38 p.

Chowns, T.M., 1972, Depositional environments in the Upper Ordovician of northwest Georgia and southeast Tennessee, in Chowns, T.M., ed., Sedimentary environments in the Paleozoic rocks of northwest Georgia: Georgia Geological Survey Guidebook 11, p. 3-11.

Chowns, T.M., and Carter, B.D., 1983, Stratigraphy of Middle and Upper Ordovician red beds in Georgia, in Chowns, T.M., ed., Geology of Paleozoic rocks in the vicinity of Rome, Georgia: Georgia Geological Society 18th Annual Field Trip Guidebook, p. 1-15.

Chowns, T.M., and McKinney, F.K., 1980, Depositional facies in Middle-Upper Ordovician and Silurian rocks in Alabama and Georgia, in Frey, R.W., ed., Excursions in southeastern geology, v. 2: Washington, D.C., American Geological Institute, p. 323-348.

Chowns, T.M., and Williams, C.T., 1983, Pre-Cretaceous rocks beneath the Georgia Coastal Plain -- Regional implications, in Gohn, G.S., ed., Studies related to the Charleston, South Carolina, earthquake of 1886 -- Tectonics and seismicity: U.S. Geological Survey Professional Paper 1313, p. L1-L42.

Clarke, J.W., 1952, Geology and mineral resources of the Thomaston quadrangle, Georgia: Georgia Geological Survey Bulletin 59, 99 p.

Clarke, O.M., and Carrington, T.J., 1964, Hillabee Chlorite Schist, in Deininger, R.W., and others, Alabama Piedmont geology: Alabama Geological Society 2nd Annual Field Trip Guide Book, p. 19-22.

Cloos, Mark, 1982, Flow melanges: numerical modeling and geologic constraints on their origin in the Franciscan subduction complex, California: Geological Society of America Bulletin, v. 93, p. 330-345.

Coleman, S.L., Medlin, J.H., and Crawford, T.J., 1973, Petrology and geochemistry of the Austell gneiss in the western Georgia Piedmont (abs.): Geological Society of America Abstracts with Programs, v. 5, no. 5, p. 338.

Colton, G.W., 1970, The Appalachian basin -- Its depositional sequences and their geologic relationships, in Fisher, G.W., and others, eds., Studies of Appalachian geology - central and southern: New York, Interscience Publishers, p. 5-47.

Conant, L.C., and Swanson, V.E., 1961, Chattanooga Shale and related rocks of central Tennessee and nearby areas: U.S. Geological Survey Professional Paper 357, 91 p.

Conley, J.R., and Henika, W.S., 1970, Geology of the Philpott Reservoir quadrangle, Virginia: Virginia Division of Mineral Resources Report of Investigations 22, 46 p.

Cook, T.A., 1982, Stratigraphy and structure of the central Talladega slate belt, Alabama Appalachians, in Bearce, D.N., and others, eds., Tectonic studies in

the Talladega and Carolina slate belts, southern Appalachian orogen: Geological Society of America Special Paper 191, p. 47-59.

Cook, F.A., 1983, Some consequences of palinspastic reconstruction in the southern Appalachians: Geology, v. 11, no. 2, p. 86-89.

Cook, F.A., Albaugh, D.S., Brown, L.D., Kaufman, Sidney, Oliver, J.E., and Hatcher, R.D., Jr., 1979, Thin-skinned tectonics in the crystalline southern Appalachians; COCORP seismic-reflection profiling of the Blue Ridge and Piedmont: Geology, v. 7, no. 12, p. 563-567.

Cook, F.A., Brown, L.D., Kaufman, Sidney, Oliver, J.E., and Peterson, T., 1981, COCORP seismic profiling of the Appalachian orogen beneath the Coastal Plain of Georgia: Geological Society of America Bulletin, v. 92, p. 738-748.

Cook, F.A., and Oliver, J.E., 1981, The late Precambrian-early Paleozoic continental edge in the Appalachian orogen: American Journal of Science, v. 281, p. 993-1008.

Cooper, B.N., 1964, Relation of stratigraphy to structure in the southern Appalachians: Blacksburg, Virginia Polytechnic Institute Department of Geological Sciences Memoir 1, p. 81-114.

Costello, J.O., 1978, Shear zones in the Corbin Gneiss of Georgia: Georgia Geologic Survey Bulletin 93, p. 32-37.

Costello, J.O., and McConnell, K.I., 1983, Relationship of the Cartersville fault and the Great Smoky fault in the southern Appalachian orogen: a reinterpretation (abs.): Geological Society of America Abstracts with Programs, v. 15, no. 2, p. 94.

Costello, J.O., McConnell, K.I., and Power, W.R., 1982, Geology of late Precambrian and early Paleozoic rocks in and near the Cartersville district, Georgia: Georgia Geological Society 17th Annual Field Trip Guidebook, 40 p.

Cowan, D.S., 1974, Deformation and metamorphism of the Franciscan subduction zone complex northwest of Pacheco Pass, California: Geological Society of America Bulletin, v. 85, no. 10, p. 1623-1634.

Cowan, D.S., 1985, Structural styles in Mesozoic and Cenozoic melanges in the western Cordillera of North America: Geological Society of America Bulletin, v. 96, no. 4, p. 451-462.

Crawford, T.J., 1968a, Geologic map, Columbia County, Georgia: Central Savannah River Area Planning and Development Commission and Geology Department, University of Georgia.

Crawford, T.J., 1968b, Geologic map, Lincoln County, Georgia: Central Savannah River Area Planning and Development Commission and Geology Department, University of Georgia.

Crawford, T.J., 1968c, Geologic map, McDuffie County, Georgia: Central Savannah River Area Planning and Development Commission and Geology Department, University of Georgia.

Crawford, T.J., 1968d, Geologic map, Taliaferro County, Georgia: Central Savannah River Area Planning and Development Commission and Geology Department, University of Georgia.

Crawford, T.J., 1968e, Geologic map, Warren County, Georgia: Central Savannah River Area Planning and Development Commission and Geology Department, University of Georgia.

Crawford, T.J., 1968f, Geologic map, Wilkes County, Georgia: Central Savannah River Area Planning and Development Commission and Geology Department, University of Georgia.

Crawford, T.J., 1983, Pennsylvanian outliers in Georgia, in Chowns, T.M., ed., Geology of Paleozoic rocks in the vicinity of Rome, Georgia: Georgia Geological Society 18th Annual Field Trip Guidebook, p. 30-41.

Crawford, T.J., and Medlin, J.H., 1973, The western Georgia Piedmont between the Cartersville and Brevard fault zones: American Journal of Science, v. 273, p. 712-722.

Crawford, T.J., and Medlin, J.H., 1974, Brevard fault zone in western Georgia and eastern Alabama: Georgia Geological Survey Guidebook 12, p. 1-1-1-67.

Crawford, T.J., and Cressler, C.W., 1982, Talladega "Series," Great Smoky fault, and Emerson fault: relationships in the Cartersville area, Georgia, in Bearce, D.N., and others, eds., Tectonic studies in the Talladega and Carolina slate belts, southern Appalachian orogen: Geological Society of America Special Paper 191, p. 31-34.

Crawford, T.J., Hurst, V.J., and Ramspott, L.D., 1966, Extrusive volcanics and associated dike swarms in central-east Georgia: Athens, University of Georgia Geology Department, Guidebook, Field Trip no. 2, Geological Society of America Southeastern Section Meeting 1966, 53 p.

Cressler, C.W., 1963, Geology and ground-water resources of Catoosa County, Georgia: Georgia Geological Survey Information Circular 28, 19 p.

Cressler, C.W., 1964a, Geology and ground-water resources of the Paleozoic rock area, Chattooga County, Georgia: Georgia Geological Survey Information Circular 27, 14 p.

Cressler, C.W., 1964b, Geology and ground-water resources of Walker County, Georgia: Georgia Geological Survey Information Circular 29, 15 p.

Cressler, C.W., 1970, Geology and ground-water resources of Floyd and Polk Counties, Georgia: Georgia Geological Survey Information Circular 39, 95 p.

Cressler, C.W., 1974, Geology and ground-water resources of Gordon, Whitfield, and Murray Counties, Georgia: Georgia Geological Survey Information Circular 47, 56 p.

Cressler, C.W., Blanchard, H.E., Jr., and Hester, W.G., 1979, Geohydrology of Bartow, Cherokee, and Forsyth Counties, Georgia: Georgia Geologic Survey Information Circular 50, 45 p.

Crickmay, G.W., 1930, The occurrence of mylonites in the crystalline rocks of Georgia: American Journal of Science, 5th series, v. 26, no. 152, p. 161-177.

Crickmay, G.W., 1936, Status of the Talladega Series in southern Appalachian stratigraphy: Geological Society of America Bulletin, v. 47, p. 1371-1392.

Crickmay, G.W., 1939, Geologic map of Georgia: Georgia Geological Survey, scale 1:500,000.

Crickmay, G.W., 1952, Geology of the crystalline rocks of Georgia: Georgia Geological Survey Bulletin 58, 54 p.

Croft, M.G., 1963, Geology and ground-water resources of Bartow County, Georgia: U.S. Geological Survey Water-Supply Paper 1619-FF, 87 p.

Crowley, W.P., 1976, The geology of the crystalline rocks near Baltimore and its bearing on the evolution of the eastern Maryland Piedmont: Baltimore, Maryland Geological Survey Report of Investigations 27, 40 p.

Dallmeyer, R.D., 1974, Eclogite intrusions in an alpine peridotite sill, Georgia-North Carolina: their chemistry and petrogenetic evolution: American Journal of Science, v. 274, p. 356-377.

Dallmeyer, R.D., 1975, $^{40}Ar/^{39}Ar$ age spectra of biotite from Grenville basement gneisses in northwest Georgia: Geological Society of America Bulletin, v. 86, no. 12, p. 1740-1744.

Dallmeyer, R.D., 1978, ^{40}Ar-^{39}Ar incremental-release ages of hornblende and biotite across the Georgia inner Piedmont: Their bearing on late Paleozoic-early Mesozoic tectonothermal history: American Journal of Science, v. 278, p. 124-129.

Dallmeyer, R.D., Courtney, P.S., and Wooten, R.M., 1978, Stratigraphy, structure, and metamorphism east of the Murphy syncline: Georgia-North Carolina: Georgia Geological Society Guidebook 17, 74 p.

Dallmeyer, R.D., and Hatcher, R.D., Jr., 1985, The Alto allochthon: Part 2, geochronological constraints on tectonothermal evolution: Geological Society of America Abstracts with Programs, v. 17, no. 2, p. 86.

Davis, G.J., 1980, The southwestern extension of the Middleton-Lowndesville cataclastic zone in the Greensboro, Georgia area and its regional implications. Athens, University of Georgia, unpublished M.S. thesis, 151 p.

Dewey, J.F., 1969, The evolution of the Caledonian/Appalachian orogen: Nature, v. 222, p. 124-128.

Dewey, J.F., and Bird, J.M., 1971, Origin and emplacement of the ophiolite suite: Appalachian ophiolites in Newfoundland: Journal of Geophysical Research, v. 76, p. 3179-3206.

Drahovzal, J.A., and Neathery, T.L., 1971, Middle and Upper Ordovician stratigraphy of the Alabama Appalachians, in Drahovzal, J.A., and Neathery, T.L., eds., The Middle and Upper Ordovician of the Alabama Appalachians: Alabama Geological Society Ninth Annual Field Trip Guidebook, p. 1-62.

Drake, A.A., Jr., and Lyttle, P.T., 1981, The Accotink Schist, Lake Barcroft Metasandstone, and Popes Head Formation -- keys to an understanding of the tectonic evolution of the northern Virginia Piedmont: U.S. Geological Survey Professional Paper 1205, 16 p.

Drake, A.A., Jr., and Morgan, B.A., 1981, The Piney Branch Complex - A metamorphosed fragment of the central Appalachian ophiolite in northern Virginia: American Journal of Science, v. 281, p. 484-508.

Dribus, J.R., Heimlich, R.A., and Palmer, D.F., 1977, Petrology and petrofabric analysis of the Deposit No. 9 dunite, Macon County, North Carolina (abs.): Geological Society of America Abstracts with Programs, v. 9, no. 2, p. 135.

Dunn, D.E., Butler, J.R., and Justus, P.S., 1968, Discussion -- Brevard zone compared to Alpine root zones: American Journal of Science, v. 266, p. 215-219.

Eardley, A.J., 1954, Structural geology of North America: New York, Harper and Brothers, 624 p.

Ernst, W.G., 1972, Occurrence and mineralogic evolution of blueschist belts with time: American Journal of Science, v. 272, no. 7, p. 657-668.

Espenshade, G.H., 1970, Geology of the northern part of the Blue Ridge anticlinorium, in Fisher, G.W., and others, eds., Studies of Appalachian geology -- central and southern: New York, Interscience Publishers, p. 199-211.

Fairley, W.M., 1965, The Murphy syncline in the Tate quadrangle, Georgia: Georgia Geological Survey Bulletin 75, 71 p.

Fairley, W.M., 1966, The Cartersville thrust at Cartersville, Georgia, in Bentley, R.D., Fairley, W.M., Fields, H.H., Power, W.R., and Smith, J.M., eds., The Cartersville fault problem: Georgia Geological Survey Geological Guidebook Series Guidebook No. 4, p. 28-33.

Fairley, W.M., 1969, Stratigraphy and structure of the Murphy Marble belt in parts of northern Georgia: Georgia Geological Survey Bulletin 80, p. 89-120.

Fairley, W.M., 1973, Correlations of stratigraphic belts of the northwest Georgia Piedmont and Blue Ridge: American Journal of Science, v. 273, no. 8, p. 686-697.

Finney, S.C., 1978, The affinities of Isograptus, Glossograptus, Cryptograptus, Corynoidea, and allied graptolites: Acta Palaeontol. Polonica, v. 23, no. 4, p. 481-495.

Finney, S.C., 1980, Thamnograptid, Dichograptid and Abrograptid graptolites from the Middle Ordovician Athens Shale of Alabama: Journal of Paleontology, v. 54, no. 6, p. 1184-1208.

Fisher, D.W., 1969, Quinquallochthonous succession and a new molasse in the southern Hudson Valley and their bearing on New York tectonic history (abs.): Geological Society of America Abstracts with Programs, v. 1, p. 66.

Fisher, D.W., 1979, Folding in the foreland, Middle Ordovician Dolgeville facies, Mohawk Valley, New York: Geology, v. 7, p. 455-459.
Fleming, G., Nunan, A., and Neilson, M.J., 1980, The Red Ridge Complex (abs.): Alabama Academy of Science Journal, v. 51, p. 201.
Fleuty, M.J., 1964, The description of folds: Geologists' Association of London, Proceedings, v. 75, pt. 4, p. 461-492.
Forrest, J.T., 1975, Geologic evaluation of a portion of the Murphy Marble belt in southwestern North Carolina: Houston, Rice University, unpublished Ph.D. dissertation, 76 p.
Fullagar, P.D., 1971, Age and origin of plutonic intrusions in the Piedmont of the southeastern Appalachians: Geological Society of America Bulletin, v. 82, p. 2845-2862.
Fullagar, P.D., 1981, Summary of Rb-Sr whole-rock ages for South Carolina: South Carolina Geology, v. 25, p. 29-31.
Fullagar, P.D., 1983, Post-metamorphic Siluro-Devonian granitic plutons in the Charlotte belt of South Carolina (abs.): Geological Society of America Abstracts with Programs, v. 15, no. 2, p. 64.
Fullagar, P.D., and Butler, J.R., 1979, 325 to 265 m.y.-old granitic plutons in the Piedmont of the southeastern Appalachians: American Journal of Science, v. 279, p. 161-185.
Furcron, A.S., Teague, K.H., and Calver, J.L., 1947, Talc deposits of Murray County, Georgia: Georgia Geological Survey Bulletin 53, 75 p.
Gale, G.H., and Pearce, J.A., 1982, Geochemical patterns in Norwegian greenstones: National Research Council of Canada 1982, p. 385-397.
Galpin, S.L., 1915, The feldspar and mica deposits of Georgia: Georgia Geological Survey Bulletin 53, 190 p.
Georgia Geological Survey, 1976, Geologic map of Georgia: Georgia Geological Survey, scale 1:500,000.
Gibson, G.G., Teeter, S.A., and Fedonkin, M.A., 1984, Ediacarian fossils from the Carolina slate belt, Stanly County, North Carolina: Geology, v. 12, no. 7, p. 387-390.
Gilbert, O.E., Jr., 1970, The Taconic orogeny in Alabama, in Drahovzal, J.A., and Neathery, T.L., eds., The Middle and Upper Ordovician of the Alabama Appalachians: Alabama Geological Society Guidebook, 9th Annual Field Trip, p. 153-171.
Gilbert, O.E., Jr., The Sylacauga unconformity/Talladega fault: the Piedmont metamorphic fron of Alabama as a stratigraphically controlled fault, in Carrington, R.J., ed., Talladega metamorphic
front: Alabama Geological Society Guidebook, 11th Annual Field Trip, p. 39-50.
Gillon, K.A., 1982, Stratigraphic, structural, and metamorphic geology of portions of the Cowrock and Helen, Georgia 7 1/2' quadrangles: Athens, University of Georgia unpublished M.S. thesis, 236 p.
Glover, Lynn, III, and Sinha, A.K., 1973, The Virgilina deformation, a late Precambrian to Early Cambrian orogenic event in the central Piedmont of Virginia and North Carolina: American Journal of Science, v. 273-A, p. 234-251.
Glover, Lynn, III, Speer, J.A., Russell, G.S., and Farrar, S.S., 1983, Ages of regional metamorphism and ductile deformation in the central and southern Appalachians: Lithos, v. 16, p. 223-245.
Gottfried, David, Annell, C.S., and Schwarz, L.J., 1977, Geochemistry of subsurface basalt from the deep corehole (Clubhouse Crossroads corehole 1) near Charleston, South Carolina - Magma type and tectonic implications, in Rankin, D.W., ed., Studies related to the Charleston, South Carolina, earthquake of 1886 - A preliminary report: U.S. Geological Survey Professional Paper 1028, p.91-113.

Gottfried, David, Annell, C.S., and Byerly, G.R., 1983, Geochemistry and tectonic significance of subsurface basalts from Charleston, South Carolina: Clubhouse Crossroads test holes #2 and #3, in Gohn, G.S., ed., U.S. Geological Survey Professional Paper 1313: Studies Related to the Charleston, South Carolina, earthquake of 1886 - Tectonics and seismicity: U.S. Geological Survey Professional Paper 1313A, p. A1-A19.

Grant, W.H., 1949, Lithology and structure of the Brevard Schist and hornblende gneiss in the Lawrenceville, Georgia area: Atlanta, Emory University, unpublished M.S. thesis,

Grant, W.H., 1958, The Geology of Hart County, Georgia: Georgia Geological Survey Bulletin 67, 75 p.

Grant, W.H., 1967, Geology of the Barnesville area and Towaliga fault, Lamar County, Georgia: Georgia Geological Society Guidebook 2nd Annual Field Trip, 1967, 16 p.

Grant, W.H., 1968, Movements in the Towaliga fault zone, Pike and Lamar Counties, Georgia (abs.): Geological Society of America Abstracts with Programs, Southeastern Section 17th Annual Meeting, p. 40-41.

Grant, W.H., Size, W.B., and O'Connor, B.J., 1980, Petrology and structure of the Stone Mountain Granite and Mount Arabia migmatite, Lithonia, Georgia, in Frey, R.W., ed., Excursions in southeastern geology, v. I: Washington, D.C., American Geological Institute, p. 41-57.

Grapes, R.H., 1978, Manganiferous schists and their origin, Hidaka Mountains, Hokkaido, Japan: Contributions to Mineralogy and Petrology, v. 68, no. 1, p. 23-35.

Green, G.B., Cavaroc, V.V., Stoddard, E.F., Abdelzahir, M.A., 1982, Volcanic and volcaniclastic facies in a part of the slate belt of North Carolina, in Bearce, D.N., and others, eds., Tectonic studies in the Talladega and Carolina slate belts, southern Appalachian orogen: Geological Society of America Special Paper 191, p. 109-124.

Greenland, L.P., and Campbell, E.Y., 1974, Spectrophotometric determination of niobium in rocks: U.S. Geological Survey Journal of Research, v. 2, no. 3, p. 353-355.

Gregory, J.P., 1981, Variations in metamorphic grade in the Kings Mountain belt of north-central South Carolina, in Horton, J.W., Jr., and others, eds., Geological investigations of the Kings Mountain belt and adjacent areas in the Carolinas: Carolina Geological Society Field Trip Guidebook 1981, p. 142-146.

Griffin, R.H., 1951, Structure and petrography of the Hillabee Sill and associated metamorphics of Alabama: Alabama Geological Survey Bulletin 63, 74 p.

Griffin, V.S., Jr., 1969, Migmatitic Inner Piedmont belt of northwestern South Carolina: South Carolina State Development Board, Division of Geology, Geological Notes, v. 13, p. 87-104.

Griffin, V.S., Jr., 1970, Position of the Kings Mountain belt in Abbeville County, South Carolina: Southeastern Geology, v. 12, p. 105-113.

Griffin, V.S., 1971, Inner Piedmont belt of the southern crystalline Appalachians: Geological Society of America Bulletin, v. 82, p. 1885-1898.

Griffin, V.S., 1981, The Lowndesville belt north of the South CarolinaGeorgia border, in Horton, J.W., Jr., and others, eds., Geological investigations of the Kings Mountain belt and adjacent areas in the Carolinas: Carolina Geological Society Field Trip Guidebook 1981, p. 166-173.

Guthrie, G.M., 1984, The Kahatchee Mountain Group: A key to understanding relationships between the Lower Cambrian Chilhowee Group and the lower Murphy Group of the western Blue Ridge (abs.): Geological Society of America Abstracts with Programs, v. 16, no. 3, p. 143.

Gwinn, V.E., 1970, Kinematic patterns and estimates of lateral shortening, Valley and Ridge and Great Valley provinces, central Appalachians, south-central Pennsylvania, in Fisher, G.W., and others, eds., Studies of Appalachian geology -- central and southern: New York, Interscience Publishers, p. 127-146.

Hack, J.T., 1982, Physiographic divisions and differential uplift in the Piedmont and Blue Ridge: U.S. Geological Survey Professional Paper 1265, 49 p.

Hadley, J.B., 1970, The Ocoee Series and its possible correlatives, in Fisher, G.W., and others, eds., Studies of Appalachian geology -- central and southern: New York, Interscience Publishers, p. 247-259.

Hadley, J.B., and Nelson, A.E., 1971, Geologic map of the Knoxville quadrangle, North Carolina, Tennessee, and South Carolina: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-654, scale 1:250,000.

Hamilton, Warren, 1979, Tectonics of the Indonesian region: U.S. Geological Survey Professional Paper 1078, 345 p.

Hanson, G.N., 1980, Rare earth elements in petrogenetic studies of igneous systems: Earth and Planetary Science Annual Report, v. 8, p. 371-406.

Harland, W.B., Cox, A.V., Llewellyn, P.G., Pickton, C.A.G., Smith, A.G., and Walters, R., 1982, A geologic time scale: Cambridge, Cambridge University Press, 131 p.

Harris, A.G., Repetski, J.E., Tull, J.F., and Bearce, D.N., 1984, Early Paleozoic conodonts from the Talladega slate belt of the Alabama Appalachians -- Tectonic implications (abs.): Geological Society of America Abstracts with Programs, v. 16, no. 3, p. 143.

Harris, L.D., and Bayer, K.C., 1979, Sequential development of the Appalachian orogen above a master decollement -- a hypothesis: Geology, v. 7, no. 12, p. 568-572.

Hartley, M.E., III, 1973, Ultramafic and related rocks in the vicinity of Lake Chatuge: Georgia Geological Survey Bulletin 85, 61 p.

Hartley, M.E., III, and Penley, H.M., 1974, The Lake Chatuge sill outlining the Brasstown antiform: Georgia Geological Society Guidebook 13, 27 p.

Hatcher, R.D., Jr., 1969, Stratigraphy, petrology and structure of the Brevard zone and Poor Mountain area, Northwesternmost South Carolina: Carolina Geological Society Guide Book, South Carolina Development Board, Division of Geology, Geological Notes, v. 13, no. 4, p. 105-141.

Hatcher, R.D., Jr., 1970, Stratigraphy of the Brevard zone and Poor Mountain area, northwestern South Carolina: Geological Society of America Bulletin, v. 81, p. 933-940.

Hatcher, R.D., Jr., 1971a, Stratigraphic, petrologic and structural evidence favoring a thrust solution to the Brevard problem: American Journal of Science, v. 270, p. 177-202.

Hatcher, R.D., Jr., 1971b, The geology of Rabun and Habersham Counties, Georgia: Georgia Geological Survey Bulletin 83, 48 p.

Hatcher, R.D., Jr., 1972, Developmental model for the southern Appalachians: Geological Society of America Bulletin, v. 83, no. 9, p. 2735-2760.

Hatcher, R.D., Jr., 1973, Basement versus cover rocks in the Blue Ridge of northeast Georgia, northwestern South Carolina, and adjacent North Carolina: American Journal of Science, v. 273, no. 8, p. 671-685.

Hatcher, R.D., Jr., 1974, An Introduction to the Blue Ridge tectonic history of northeast Georgia: Georgia Geological Survey Guidebook 13-A, 60 p.

Hatcher, R.D., Jr., 1983, Basement massifs in the Appalachians: their role in deformation during the Appalachian orogenies: Geological Journal, v. 18, p. 255-263.

Hatcher, R.D., Jr., 1976, Introduction to the geology of the eastern Blue Ridge of the Carolinas and nearby Georgia: Carolina Geological Society Guidebook 1976, 53 p.

Hatcher, R.D., Jr., 1978a, Tectonics of the western Piedmont and Blue Ridge, southern Appalachians: review and speculation: American Journal of Science, v. 278, p. 276-301.

Hatcher, R.D., Jr., 1978b, The Alto Allochthon: a major tectonic unit of the northeast Georgia Piedmont: Georgia Geological Survey Bulletin 93, p. 83-86.

Hatcher, R.D., Jr., 1981, Thrusts and nappes in the North American Appalachian orogen, in McClay, K.R., and Price, N.J., eds., Thrust and nappe tectonics: Geological Society of London Special Publication Number 9, p. 491-499.

Hatcher, R.D., Jr., 1983, Basement massifs in the Appalachians: their role in deformation during the Appalachian orogenies: Geological Journal, v. 18, p. 255-265.

Hatcher, R.D., Jr., and Butler, J.R., 1979, Guidebook for Southern Appalachian Field Trip: International Geological Correlations Program, 117 p.

Hatcher, R.D., Jr., Hooper, R.J., and Odom, A.L., 1983, The Pine Mountain window, Georgia, Alabama: A detached basement massif flanked by the Avalonian suture (abs.): Geological Society of America Abstracts with Programs, v. 15, no. 2, p. 110.

Hatcher, R.D., Jr., Hooper, R.J., Petty, S.S., and Willis, J.D., 1981, Tectonics of emplacement and origin of Appalachian ultramafic bodies (abs.): Geological Society of America Abstracts with Programs, v. 13, no. 7, p. 469-470.

Hatcher, R.D., Jr., Hooper, R.J., Petty, S.S., and Willis, J.D., 1984, Structure and chemical petrology of three southern Appalachian mafic-ultramafic complexes and their bearing upon the tectonics of emplacement and origin of Appalachian ultramafic bodies: American Journal of Science, v. 284, p. 484-506.

Hatcher, R.D., Jr., Howell, D.E., and Talwani, Pradeep, 1977, Eastern Piedmont fault system: speculations on its extent: Geology, v. 5, no. 10, p.636-640.

Hatcher, R.D., Jr., and Odom, A.L., 1980, Timing of thrusting in the southern Appalachians, USA: model for orogeny?: Journal of the Geological Society of London, v. 137, p. 321-327.

Hatcher, R.D., Jr., and Zietz, Isidore, 1978, Thin crystalline thrust sheets in the southern Appalachians Inner Piedmont and Blue Ridge: interpretation based upon regional aeromagnetic data (abs.): Geological Society of America Abstracts with Programs, v. 10, p. 417.

Hatcher, R.D., Jr., and Zietz, Isidore, 1980, Tectonic implications of regional aeromagnetic and gravity data from the southern Appalachians, in Wones, D.R., ed., Proceedings "The Caledonides in the U.S.A.": Virginia Polytechnical Institute and State University Memoir 2, p. 235-244.

Hayes, C.W., 1891, The overthrust faults of the southern Appalachians: Geological Society of America Bulletin, v. 2, p. 141-154.

Hayes, C.W., 1901, Geological relations of the iron ores in the Cartersville District, Georgia: American Institute of Mining Engineers Transactions, v. 30, p. 403-419.

Hedberg, H.D, ed., 1976, International stratigraphic guide - a guide to stratigraphic classification, terminology, and proceedure: New York, Wiley and Sons, 200 p.

Herndon, R.M., 1964, Geologic maps and sections of the Ducktown, Isabella, and Persimmon Creek quadrangles, Tennessee and North Carolina: U.S. Geological Survey open-file maps, scale 1:24,000.

Herndon, R.M., 1968, Geology of the Ducktown, Isabella, and Persimmon Creek quadrangles, Tennessee and North Carolina: U.S. Geological Survey open-file report, 71 p.

Hewett, D.F., and Crickmay, G.W., 1937, The warm springs of Georgia, their geologic relations and origin: a summary report: U.S. Geological Survey Water Supply Paper 819, 40 p.

Higgins, M.W., 1965, The geology of part of Sandy Springs quadrangle, Georgia: Atlanta, Emory University, unpublished M.S. thesis, 141 p.

Higgins, M.W., 1966, The geology of the Brevard lineament near Atlanta, Georgia: Georgia Geological Survey Bulletin 77, 49 p.

Higgins, M.W., 1971, Cataclastic rocks: U.S. Geological Survey Professional Paper 687, 97 p.

Higgins, M.W., and Atkins, R.L., 1981, The stratigraphy of the Piedmont southeast of the Brevard Zone in the Atlanta, Georgia, area, in Wigley, P.B., ed., Latest thinking on the stratigraphy of selected areas in Georgia: Georgia Geologic Survey Information Circular 54-A, p. 3-40.

Higgins, M.W., Atkins, R.L., Crawford, T.J., Crawford, R.F., III, and Cook, R.B., 1984, A brief excursion through two thrust stacks that comprise most of the crystalline terrane of Georgia and Alabama: Georgia Geological Society, Guidebook 9th Annual Field Trip, 67 p.

Higgins, M.W., and McConnell, K.I., 1978, The Sandy Springs Group and related rocks in the Georgia Piedmont; nomenclature and stratigraphy: Georgia Geological Survey Bulletin 93, p. 50-55.

Higgins, M.W., Pickering, S.M., Jr., and Atkins, R.L., 1980, The Soapstone Ridge Complex, Atlanta, Georgia: a transported mafic-ultramafic complex in the southeastern Appalachian Piedmont (abs.): Geological Society of America Abstracts with Programs, v. 12, no. 7, p. 446.

Higgins, M.W., Sinha, A.K., Zartman, R.E., and Kirk, W.S., 1977, U-Pb zircon dates from the central Appalachian Piedmont; a possible case of inherited radiogenic lead: Geological Society of America Bulletin, v. 88, no. 1, p. 125-132.

Higgins, M.W., and Zietz, Isidore, 1975, Geologic interpretation of aeromagnetic and aeroradioactivity maps of northern Georgia: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-783, scale 1:500,000, text 16 p.

Hopkins, O.B., 1914, Asbestos, talc, and soapstone deposits of Georgia: Georgia Geological Survey Bulletin 29, 319 p.

Hopson, J.L., Thompson, R.H., Hatcher, R.D., Jr., and Dallmeyer, R.D., 1985, The Alto allochthon: Part I, results of structural and stratigraphic studies (abs.): Geological Society of America Abstracts with Programs, v. 17, no. 2, p. 96.

Horton, J.W., Jr., 1981a, Geologic map of the Kings Mountain belt between Gaffney, South Carolina, and Lincolnton, North Carolina, in Horton, J.W., Jr., and others, eds., Geological investigations of the Kings Mountain belt and adjacent areas in the Carolinas: Carolina Geological Society Field Trip Guidebook 1981, p. 6-18.

Horton, J.W., Jr., 1981b, Shear zone between the Inner Piedmont and Kings Mountain belts in the Carolinas: Geology, v. 9, p. 28-33.

Horton, J.W., Jr., and Butler, J.R., 1981, Geology and mining history of the Kings Mountain belt in the Carolinas -- A summary and status report, in Horton, J.W., Jr., and others, eds., Geological investigations of the Kings Mountain belt and adjacent areas in the Carolinas: Carolina Geological Society Field Trip Guidebook 1981, p. 194-212.

Horton, J.W., Jr., Stoddard, E.F., Wylie, A.S., Jr., Moye, R.J., Jr., and Blake, D.E., 1985, Melange terrane in the eastern Piedmont, North Carolina (abs.): Geological Society of America Abstracts with Programs, v. 17, no. 2, p. 96.

Howell, D.E., and Pirkle, W.A., 1976, Geologic sections across the Modoc fault zone, Modoc, South Carolina, in Chowns, T.M., compiler, Stratigraphy, struc-

ture, and seismicity in slate belt rocks along the Savannah River: Georgia Geologic Survey Guidebook 16, p. 16-20.

Hsu, K.J., 1968, Principles of melanges and their bearing on the Franciscan-Knoxville paradox: Geological Society of America Bulletin, v. 79, p. 1063-1074.

Hull, J.P.D., LaForge, Laurence, and Crane, W.R., 1919, Report on the manganese deposits of Georgia: Georgia Geological Survey Bulletin 35, 66 p.

Hurst, V.J., 1955, Stratigraphy, structure, and mineral resources of the Mineral Bluff quadrangle, Georgia: Georgia Geological Survey Bulletin 63, 137 p.

Hurst, V.J., 1970, The Piedmont in Georgia, in Fisher, G.W., and others, eds., Studies of Appalachian geology -- central and southern: New York, Interscience Publishers, p. 383-396.

Hurst, V.J., 1973, Geology of the southern Blue Ridge belt: American Journal of Science, v. 273, no. 8, p. 643-670.

Hurst, V.J., and Crawford, T.J., 1964, Exploration of mineral deposits in Habersham County, Georgia: U.S. Department of Commerce, Area Redevelopment Administration, 180 p.

Hurst, V.J., and Crawford, T.J., 1970, Sulfide deposits, Coosa Valley area, Georgia: U.S. Department of Commerce, Economic Development Administration, 190 p.

Hurst, V.J., and Jones, L.M., 1973, Origin of amphibolites in the Cartersville-Villa Rica area, Georgia: Geological Society of America Bulletin, v. 84, p. 905-912.

Hurst, V.J., and Schlee, J.S., 1962, Ocoee metasediments of north central Georgia-southeast Tennessee: Georgia Geological Survey Guidebook No. 3, 28 p.

Irvine, T.N., and Baragar, W.R.A., 1971, A guide to the chemical classification of the common volanic rocks: Canadian Journal of Earth Science, v. 8, p. 523-548.

Irving, E., and Strong, D.F., 1984, Evidence against large-scale Carboniferous strike-slip faulting in the Appalachian-Caledonian orogen: Nature, v. 310, p. 762-764.

Iverson, W.P., and Smithson, S.B., 1982, Master decollement root zone beneath the southern Appalachians and crustal balance: Geology, v. 10, no. 5, p. 241-245.

Iverson, W.P., and Smithson, S.B., 1983, Reprocessed COCORP southern Appalachian reflection data: root zone to Coastal Plain: Geology, v. 11, no. 7, p. 422-425.

Jackson, L.E., Jr., 1951, The study of the Blackford breccia in the Dalton quadrangle: Atlanta, Emory University, unpublished M.S. thesis, 44 p.

Jakes, P., and White, A.F.R., 1973, Major and trace element abundance in volcanic rocks of orogenic areas: Geological Society of America Bulletin, v. 84, p. 29-40.

Jonas, A.I., 1932, Structure of the metamorphic belt of the southern Appalachians: American Journal of Science, v. 224, p. 228-243.

Jones, L.M., Carpenter, R.H., Whitney, J.A., and Walker, R.L., 1974, Rubidium-strontium age and origin of pegmatites associated with the Gladesville norite, Jasper County, Georgia (abs.): Geological Society of America Abstracts with Programs, v. 6. no. 4, p. 369.

Jones, L.M., Hurst, V.J., and Walker, R.L., 1973, Strontium isotope composition of amphibolite of the Cartersville-Villa Rica district, Georgia: Geological Society of America Bulletin, v. 84, no. 3, p. 913-918.

Keith, Arthur, 1895, Description of the Knoxville sheet (Tennessee-North Carolina): U.S. Geological Survey Geologic Atlas of the United States, Folio 16, 6 p.

Keith, Arthur, 1904, Description of the Ashville quadrangle (North Carolina-Tennessee): U.S. Geological Survey Geologic Atlas of the United States, Folio 116, 10 p.

Keith, Arthur, 1905, Description of the Mount Mitchell quadrangle (North Carolina-Tennessee): U.S. Geological Survey Geologic Atlas of the United States, Folio 124, 10 p.

Keith, Arthur, 1907a, Description of the Nantahala quadrangle (North Carolina-Tennessee): U.S. Geological Survey Geologic Atlas of the United States , Folio 143, 12 p.

Keith, Arthur, 1907b, Description of the Pisgah quadrangle (North Carolina-South Carolina): U.S. Geological Survey Geologic Atlas of the United States, Folio 147, 9 p.

Kellberg, J.M., 1943, Basic intrusives in the Chatuge Reservoir: Manuscript report, Tennessee Valley Authority Files, Knoxville, Tennessee.

Kellberg, J.M., and Grant, L.F., 1956, Coarse conglomerates of the Middle Ordovician in the south Appalachian valley: Geological Society of America Bulletin, v. 67, p. 697-716.

Kesler, T.L., 1950, Geology and mineral deposits of the Cartersville district, Georgia: U.S. Geological Survey Professional Paper 224, 97 p.

Kidd, J.T., and Neathery, T.L., 1976, Correlation between Cambrian rocks of the southern Appalachian geosyncline and the interior low plateaus: Geology, v. 4, p. 767-769.

King, P.B., 1955, A geologic cross-section across the southern Appalachians: an outline of the geology in the segment in Tennessee, North Carolina, and South Carolina, in Russell, R.J., ed., Guides to southeastern geology: Geological Society of America 1955 Annual Meeting, p. 332-373.

King, P.B., 1964, Geology of the central Great Smoky Mountains; Tennessee: U.S. Geological Survey Professional Paper 349-C, 148 p.

King, P.B., 1970, The Precambrian of the United States of America: Southeastern United States, in Rankama, Kalervo, ed., The geologic systems: The Precambrian, Volume 4: New York, Interscience - John Wiley and Sons, p. 1-71.

King, P.B., and Ferguson, H.W., 1960, Geology of northeasternmost Tennessee: U.S. Geological Survey Professional Paper 311, 136 p.

King, P.B., Hadley, J.B., Neuman, R.B., and Hamilton, Warren, 1958, Stratigraphy of the Ocoee Series, Great Smoky Mountains, Tennessee and North Carolina: Geological Society of America Bulletin, v. 69, p. 947-966.

King, P.B., Neuman, R.B., and Hadley, J.B., 1968, Geology of the Great Smoky Mountains National Park, Tennessee and North Carolina: U.S. Geological Survey Professional Paper 587, 23 p.

Kish, S.A., and Black, W.W., 1982, Part 2, the Carolina Slate belt: origin and evolution of an ancient volcanic arc, Introduction, in Bearce, D.N., and others, eds., Tectonic studies in the Talladega and Carolina slate belts, southern Appalachian orogen: Geological Society of America Special Paper 191, p. 93-97.

Kline, S.W., 1980, Sandy Springs sequence rocks southeast of the Brevard Zone, near Atlanta, Georgia, and their bearing on the nature of the zone (abs.): Geological Society of America Abstracts with Programs, v. 12, no. 4, p. 181.

Kline, S.W., 1981, The geology of the northern half of the Suwanee quadrangle, Gwinnett County, Georgia: Atlanta, Georgia Institute of Technology, unpublished M.S. thesis, 180 p.

LaForge, Laurence, and Phalen, C.C., 1913, Description of the Ellijay quadrangle (Georgia): U.S. Geological Survey Geologic Atlas of the United States, Folio 187, 17 p.

Lash, G.G., and Drake, A.A., Jr., 1984, The Richmond and Greenwich slices of the Hamburg klippe in eastern Pennsylvania -- Stratigraphy, sedimentology, structure, and plate tectonic implications: U.S. Geological Survey Professional Paper 1312, 40 p.

Laurent, Roger, 1977, Ophiolites from northern Appalachians of Quebec, in Coleman, R.G., and Irwin, W.P., eds., North American ophiolites: Oregon Department of Geology and Mineral Industries Bulletin 95, p. 25-40.

Lawrence, D.P., 1985, Tectonic significance of a Bouguer gravity survey of the Charlotte belt in west-central South Carolina (abs.): Geological Society of America Abstracts with Programs, v. 17, no. 2, p. 99.

Livingston, J.L., and Burchfiel, B.C., 1968, The root interpretation of the Brevard zone (abs.): Geological Society of America, Southeastern Section, 17th Annual Meeting, Abstracts with Programs, p. 53.

Lochman, Christina, 1956, Stratigraphy, paleontology, and paleogeography of the Elliptocephala asaphoides strata in Cambridge and Hoosick quadrangles, New York: Geological Society of America Bulletin, v. 67, p. 1331-1396.

Long, L.T., 1979, The Carolina slate belt -- Evidence of a continental rift zone: Geology, v. 7, p. 180-184.

Long, L.T., Bridges, S.R., and Dorman, L.M., 1972, Simple Bouguer gravity map of Georgia: Georgia Geological Survey Map GM-4.

Mack, G.H., 1980, Stratigraphy and depositional environments of the Chilhowee Group (Cambrian) in Georgia and Alabama: American Journal of Science, v. 280, p. 497-517.

Mack, G.H., 1985, Provenance of the Middle Ordovician Blont clastic wedge, Georgia and Tennessee: Geology, v. 13, no. 4, p. 299-302.

Maher, H.D., Jr., Palmer, A.R., Secor, D.T., and Snoke, A.W., 1981, New trilobite locality in the Piedmont of South Carolin, and its regional implications: Geology, v. 9, no. 1, p. 34-36.

Martin, B.F., 1974, The petrology of the Corbin Gneiss: Athens, University of Georgia, unpub. M.S. Thesis, 133 p.

Matthews, Vincent, III, 1967, Geology and petrology of the pegmatite district in southwestern Jasper County, Georgia: Athens, University of Georgia, unpublished M.S. thesis, 68 p.

McCalley, Henry, 1897, Report on the Valley Regions of Alabama, Part II, the Coosa Valley Region: Alabama Geological Survey Special Report 9, 826 p.

McConnell, K.I., 1980, Origin and correlation of the Pumpkinvine Creek Formation: a new unit in the Piedmont of northern Georgia: Georgia Geologic Survey Information Circular 52, 19 p.

McConnell, K.I., and Abrams, C.E., 1982, Geology of the New Georgia Group and associated massive sulfide and gold deposits: West-central Georgia: Guidebook, Exploration for metallic resources in the southeast symposium: Athens, University of Georgia Center for Continuing Education, p. 143-170.

McConnell, K.I., and Abrams, C.E., 1983, Geochemistry of metamorphosed banded iron formation and alumino-silicate assemblages of western Georgia (abs.): Geological Society of America Abstracts with Programs, v. 15, no. 2, p. 90.

McConnell, K.I., and Abrams, C.E., 1984, Geology of the greater Atlanta region: Georgia Geologic Survey Bulletin 96, 127 p.

McConnell, K.I., and Costello, J.O., 1980, Guide to geology along a traverse through the Blue Ridge and Piedmont provences of north Georgia, in Frey, R.W., ed., Excursions in southeastern geology, v. I: Washington, D.C., American Geological Institute, p. 241-258.

McConnell, K.I., and Costello, J.O., 1982, Relationship between Talladega belt rocks and Ocoee Supergroup rocks near Cartersville, Georgia in Bearce, D.N., and others, eds., Tectonic studies in the Talladega and Carolina slate belts, southern Appalachian orogen: Geological Society of America Special Paper 191, p. 19-30.

McConnell, K.I., and Costello, J.O., 1984, Basement-cover relationships along the western edge of the Blue Ridge thrust sheet in Georgia, in Bartholomew, M.J.,

ed., The Grenville event in the Appalachians and related topics: Geological Society of America Special Paper 194, p.263-280.

McElhaney, M.S., and McSween, H.Y., Jr., 1983, Petrology of the Chunky Gal Mountain mafic-ultramafic complex, North Carolina: Geological Society of America Bulletin, v. 94, no. 7, p. 855-874.

McLemore, W.H., 1965, The geology of the Pollard's Corner area, Columbia County, Georgia: Athens, University of Georgia, unpublished M.S. thesis, 49 p.

McSween, H.Y., Jr., Sando, T.W., Clark, S.R., Harden, J.T., and Strange, E.A., 1984, The gabbro-metagabbro association of the southern Appalachian Piedmont: American Journal of Science, v. 284, p. 437-461.

Medlin, J.H., and Crawford, T.J., 1973, Stratigraphy and structure along the Brevard Fault Zone in western Georgia and Alabama: American Journal of Science, v. 273-A, p. 89-104.

Mellen, James, 1956, Precambrian sedimentation in the northern part of the Cohutta Mountain quadrangle, Georgia: Georgia Mineral Newsletter, v. IX, p. 46-61.

Milici, R.C., 1969, Middle Ordovician stratigraphy in central Sequatchie Valley, Tennessee: Southeastern Geology, v. 11, no. 2, p. 111-127.

Milici, R.C., 1973, The stratigraphy of Knox County, Tennessee, in Geology of Knox County, Tennessee: Tennessee Division of Geology Bulletin 70, p. 9-24.

Milici, R.C., and Smith, J.W., 1969, Stratigraphy of the Chickamauga Supergroup in its type locality: Georgia Geological Survey Bulletin 80, p. 5-35.

Milici, R.C., and Wedow, Helmuth, Jr., 1977, Upper Ordovician and Silurian stratigraphy in Sequatchie Valley and parts of adjacent Valley and Ridge, Tennessee: U.S. Geological Survey Professional Paper 996, 38 p.

Milton, Charles, and Hurst, V.J., 1965, Subsurface "basement" rocks of Georgia: Georgia Geological Survey Bulletin 76, 56 p.

Mohr, D.W., 1973, Stratigraphy and structure of part of the Great Smoky and Murphy belt groups, western North Carolina: American Journal of Science, v. 273-A, p. 41-47.

Moore, J.C., and Biju-Duval, Bernard, 1984, 33. Tectonic synthesis, Deep Sea Drilling Project Leg 78A: Structural evolution of offscraped and underthrust sediment, northern Barbados Ridge Complex, in Initial Reports Deep Sea Drilling Project, 78A: U.S. Government Printing Office, p.601-613.

Moore, J.C., Watkins, J.S., and Shipley, T.H., 1981, Summary of accretionary processes, Deep Sea Drilling Project Leg 66: Offscraping, underplating, and deformation of the slope apron, in Initial Reports of the Deep Sea Drilling Project, 66: U.S. Government Printing Office, p. 825-836.

Moore, J.C., Cowan, D.S., and Karig, D.E., 1985, Structural styles and deformation fabrics of accretionary complexes: Geology, v. 13, no. 1, p. 77-79.

Morgan, B.A., 1977, The Baltimore Complex, Maryland, Pennsylvania, and Virginia, in Coleman, R.G., and Irwin, W.P., eds., North American ophiolites: Oregon Department of Geology and Mineral Industries Bulletin 95, p. 41-49.

Munyan, A.C., 1951, Geology and mineral resources of the Dalton quadrangle, Georgia-Tennessee: Georgia Geological Survey Bulletin 57, 128 p.

Murphy, C.F., and Butler, J.R., 1981, Geology of the northern half of the Kings Creek quadrangle, South Carolina, in Horton, J.W., Jr., and others, eds., Geological investigations of the Kings Mountain belt and adjacent areas in the Carolinas: Carolina Geological Society Field Trip Guidebook 1981, p. 49-64.

Neathery, T.L., 1972, Notes on the stratigraphy of the Hillabee Chlorite Schist in the new Piedmont geology (abs.): Journal Alabama Academy of Science, v. 43, no. 3, p. 186.

Neathery, T.L., 1975, Rock units in the high-rank belt of the northern Alabama Piedmont, in Neathery, T.L., and Tull, J.F., eds., Geologic profiles of the northern Alabama Piedmont: Alabama Geological Society Guidebook, 13th Annual Field Trip, p. 9-47.

Neathery, T.L., 1986, Geology and mineral resources of Etowah County, Alabama: Tuscaloosa, Alabama Geological Survey Bulletin, in press.

Neathery, T.L., and Drahovzal, J.A., 1971, Stop 3 Hensley Mountain Section, in Drahovzal, J.A., and Neathery, T.L., eds., The Middle and Upper Ordovician of the Alabama Appalachians: Alabama Geological Society Ninth Annual Field Trip Guidebook, p. 185-188.

Neathery, T.L., and Reynolds, J.W., 1973, Stratigraphy and metamorphism of the Wedowee Group: a reconnaissance: American Journal of Science, v. 273, p. 723-741.

Needham, R.E., 1972, The Geology of the Murray County, Georgia, Talc District: Athens, University of Georgia, unpublished M.S. thesis, 107 p.

Neilson, M.J., 1983, Structure and stratigraphy of the Dadeville Group within the Tallassee synform, Tallapoosa County, Alabama (abs.): Geological Society of America Abstracts with Programs, v. 15, no. 2, p. 110.

Nelson, A.E., 1981, Polydeformed rocks of the Lowndesville shear zone in the Greenville 2° quadrangle, South Carolina and Georgia, in Horton, J.W., Jr., and others, eds., Geological investigations of the Kings Mountain belt and adjacent areas in the Carolinas: Carolina Geological Society Field Trip Guidebook 1981, p. 181-193.

Nelson, A.E., 1982, Geologic map of the Tray Mountain Roadless Area, northern Georgia: U.S. Geological Survey Miscellaneous Field Studies Map Mf-1347-A, scale: 1:30,000.

Neuman, R.B., 1955, Middle Ordovician rocks of the Tellico-Sevier belt eastern Tennessee: U.S. Geological Survey Professional Paper 274-F, p. 141-178.

Nisbet, E.G., and Pearce, J.A., 1973, TiO_2 as a possible guide to past spreading rates: Nature, v. 246, p. 468-470.

North American Commission on Stratigraphic Nomenclature, 1983, North American stratigraphic code: American Association of Petroleum Geologists Bulletin, v. 67, p. 841-875.

Odom, A.L., and Fullagar, P.D., 1971, A major discordancy between U-Pb zircon ages and Rb-Sr whole rock ages of late-Precambrian granites in the Blue Ridge province (abs.): Geological Society of America Abstracts with Programs, v. 3, no. 7, p. 663.

Odom, A.L., and Fullagar, P.D., 1973, Geochronologic and tectonic relationships between the Inner Piedmont, Brevard Zone, and Blue Ridge belts, North Carolina: American Journal of Science, v. 273-A, p. 133-149.

Odom, A.L., and Hatcher, R.D., Jr., 1980, A characterization of faults in the Appalachian foldbelt: U.S. Nuclear Regulatory Commission, NUREG/CR-1621, 314 p.

Odom, A.L., Kish, S.A., and Leggo, P.L., 1973, Extension of "Grenville basement" to the southern extremity of the Appalachians: U-Pb ages on zircons (abs.): Geological Society of America Abstracts with Programs, v. 5, no. 5, p. 425.

Overstreet, W.C., and Bell, Henry, III, 1965, The crystalline rocks of South Carolina: U.S. Geological Survey Bulletin 1183, 126 p.

Palmer, A.R., 1971, The Cambrian of the Appalachian and eastern New England regions, eastern United States, in Holland, C.H., ed., Cambrian of the New World: New York, Interscience Publishers, p. 169-217.

Palmer, A.R., 1983, The Decade of North American Geology 1983 geologic time scale: Geology, v. 11, p. 503-504.

Parker, J.M., III, 1979, Geology and mineral resources of Wake County: North Carolina Department of Natural Resources and Community Development, Division of Land Resources, Geological Survey Section Bulletin 86, 122 p.

Pate, M.L., 1980, Gold, pyrite and asbestos deposits of the Villa Rica mining district, west-central Georgia -- A preliminary report: Georgia Geologic Survey Open-File Report 81-3, 24 p.

Pavlides, Louis, 1981, The central Virginia volcanic-plutonic belt: an island arc of Cambrian(?) age: U.S. Geological Survey Professional Paper 1231-A, 34 p.
Peacock, M.A., 1931, Classification of igneous rocks: Journal of Geology, v. 39, p. 54-67.
Pearce, J.A., 1975, Basalt geochemistry used to investigate past-tectonic environments on Cyprus: Tectonophysics, v. 25, p. 41-67.
Pearce, J.A., 1979, Geochemical evidence for the genesis and eruptive setting of lavas from Tethyan ophiolites, in Panayiotow, A., ed., Ophiolites, Proceedings of the International Ophiolite Symposium, Cyprus: Cyprus Geological Survey Department, p. 261-272.
Pearce, J.A., and Cann, J.R., 1973, Tectonic setting of basic volcanic rocks determined using trace element analyses: Earth and Planetary Science Letters, v. 19, n0. 2, p. 290-300.
Pearce, J.A., and Norry, M.J., 1979, Petrogenetic indications of Ti, Zr, Y, and Nb variations in volcanic rocks: Contributions to Mineralogy and Petrology, v. 69, p. 33-47.
Pendexter, W.S., 1982, Stratigraphic relationships of the carbonate sequence in the Talladega slate belt, Chilton and Coosa Counties, Alabama, in Bearce, D.N., and others, eds., Tectonic studies in the Talladega and Carolina slate belts, southern Appalachian orogen: Geological Society of America Special Paper 191, p. 61-68.
Petty, S.M., and Hatcher, R.D., Jr., 1980, The Laurel Creek mafic-ultramafic complex, northeast Georgia: intrusive complex or ophiolite? (abs.): Geological Society of America Abstracts with Programs, v. 12, no. 4, p. 205.
Pojeta, John, Jr., Kriz, Jiri, and Berdan, J.M., 1976, Silurian-Devonian pelecypods and Paleozoic stratigraphy of subsurface rocks in Florida and Georgia and related Silurian pelecypods from Bolivia and Turkey: U.S. Geological Survey Professional Paper 879, 32 p.
Posey, H.H., 1981, A model for the origin of metallic mineral deposits in the Kings Mountain belt, in Horton, J.W., Jr., and others, eds., Geological investigations of the Kings Mountain belt and adjacent areas in the Carolinas: Carolina Geological Society Field Trip Guidebook 1981, p. 130-141.
Power, W.R., and Forrest, J.T., 1971, Stratigraphy and structure of the Murphy belt, North Carolina: Carolina Geological Society Field Trip Guidebook, North Carolina Department of Natural Resources, 29 p.
Power, W.R., and Forrest, J.T., 1973, Stratigraphy and paleogeography in the Murphy Marble belt: American Journal of Science, v. 273, p. 698-711.
Prather, J.P., 1971, The geology of eastern Monroe County, Georgia: Athens, University of Georgia, unpublished M.S. thesis, 82 p.
Prather, J.P., and Radcliffe, Dennis, 1970, Petrology of the norites of Monroe County, Georgia (abs.): Geological Society of America Abstracts with Programs, v. 2, no. 3, p. 238.
Price, R.S., and Hatcher, R.D., Jr., 1983, Tectonic significance of similarities in the evolution of the Alabama-Pennsylvania Appalachians and the Alberta-British Columbia Canadian Cordillera, in Hatcher, R.D., Jr., and others, eds., Contributions to the tectonics and geophysics of mountain chains: Geological Society of America Memoir 158, p. 149-160.
Prouty, W.F., 1916, The crystalline and other marbles of Alabama: Alabama Geological Survey Bulletin 13, 48 p.
Prouty, W.F., 1923, Geology and mineral resources of Clay County: Alabama Geological Survey County Report No. 1, 190 p.
Prowell, D.C., 1972, Ultramafic plutons in the central Piedmont of Georgia: Atlanta, Emory University, unpublished M.S. thesis, 83 p.

Rankin, D.W., 1970, Stratigraphy and structure of Precambrian rocks in northwestern North Carolina, in Fisher, G.W., and others, eds., Studies of Appalachian geology -- central and southern: New York, Interscience Publishers, p. 227-245.

Rankin, D.W., 1975, The continental margin of eastern North America in the southern Appalachians: the opening and closing of the proto-Atlantic Ocean: American Journal of Science, v. 275-A, p. 298-336.

Rankin, D.W., 1976, Appalachian salients and recesses: late Precambrian continental breakup and the opening of the Iapetus Ocean: Journal of Geophysical Research, v. 81, no. 32, p. 5605-5619.

Rankin, D.W., Espenshade, G.H., and Shaw, K.W., 1973, Stratigraphy and structure of the metamorphic belt in northwestern North Carolina and southwestern Virginia: a study from the Blue Ridge across the Brevard fault zone to the Sauratown Mountains anticlinorium: American Journal of Science, v. 273-A, p. 1-40.

Rankin, D.W., Stern, T.W., Reed, J.C., Jr., and Newell, M.F., 1969, Zircon ages of felsic volcanic rocks in the upper Precambrian of the Blue Ridge, central and southern Appalachian Mountains: Science, v. 166, no. 3906, p. 741-744.

Ratcliffe, N.M., 1975, Cross section of the Berkshire massif at 42° N: Profile of a basement reactivation zone, in Ratcliffe, N.M., ed., Guidebook for field trips in western Massachusetts, northern Connecticut and adjacent areas of New York: New England Intercollegiate Conference 67th Annual Meeting Guidebook, p. 186-222.

Ratcliffe, N.M., 1979, Field guide to the Chatham and Greylock slices of the Taconic allochthon in western Massachusetts and their relationship to the Hoosac-Rowe sequence, in Friedman, G.M., ed., New York State Geological Association and New England Intercollegiate Conference Guidebook, p. 388-425.

Ratcliffe, N.M., and Hatch, N.L., Jr., 1979, A traverse across the Taconide zone in the area of the Berkshire massif, western Massachusetts, in Skehan, J.W., and Osberg, P.H., eds., The Caledonides in the U.S.A., Geological excursions in the northeast Appalachians: Weston, Massachusetts, Weston Observatory, p. 175-224.

Read, J.F., 1985a, Carbonate platform facies models: American Association of Petroleum Geologists Bulletin, v. 69, no. 1, p. 1-21.

Read, J.F., 1985b, Evolution of Cambrian-Ordovician carbonate shelf, United States Appalachians (abs.): American Association of Petroleum Geologists Bulletin (Association Round Table), v. 69, no. 2, p. 299.

Reed, J.C., Jr., and Bryant, Bruce, 1964, Evidence for strike-slip faulting along the Brevard zone in North Carolina: Geological Society of America Bulletin, v. 75, p. 1177-1196.

Reed, J.C., Jr., Bryant, Bruce, and Myers, W.B., 1970, The Brevard zone: a reinterpretation, in Fisher, G.W., and others, eds., Studies of Appalachian geology -- central and southern: New York, Interscience Publishers, p. 261-269.

Reed, J.C., Jr., Johnson, H.S., Bryant, Bruce, Bell, Henry, III, and Overstreet, W.C., 1961, The Brevard fault in North and South Carolina: U.S. Geological Survey Professional Paper 424-C, p. 67-70.

Reinhardt, Juergen, Prowell, D.C., and Christopher, R.A., 1984, Evidence for Cenozoic tectonism in the southwest Georgia Piedmont: Geological Society of America Bulletin, v. 95, p. 1176-1187.

Reynolds, J.W., 1972, New data on the nature of the Ashland-Hillabee contact in Clay and Coosa Counties, Alabama (abs.): Journal Alabama Academy of Science, v. 43, no. 3, p. 187.

Reynolds, J.W., 1973, Mafic and ultramafic rocks near Goodwater, Alabama: Tuscaloosa, University of Alabama, unpublished M.S. thesis, 135 p.

Rheams, K.F., 1982, The petrography and structure of the Mitchell Dam Amphibolite and the surrounding Higgins Ferry Formation, Chilton and Coosa Counties, Alabama: Tuscaloosa, University of Alabama, unpublished M.S. thesis, 124 p.

Rich, J.L., 1934, Mechanics of low-angle overthrusting as illustrated by the Cumberland overthrust block, Va., Ky., and Tenn.: American Association of Petroleum Geologists Bulletin, v. 18, p. 1584-1596.

Rich, Mark, 1983, Stratigraphy of the Floyd Formation (Meramecian-Chesterian) in the Rome area, Georgia, in Chowns, T.M., ed., Geology of Paleozoic rocks in the vicinity of Rome, Georgia: Georgia Geological Society 18th Annual Field Trip Guidebook, p. 16-29.

Rindsberg, A.K., 1982, Ichnology and paleoecology of the Sequatchie and Red Mountain Formations (Ordovician-Silurian), Georgia-Tennessee: Athens, University of Georgia, unpublished M.S. thesis, 365 p.

Rodgers, John, 1953, Geologic map of east Tennessee with explanatory text: Tennessee Division of Geology Bulletin 58, part 2, 168 p.

Rodgers, John, 1964, Basement and no-basement hypotheses in the Jura and the Appalachian Valley and Ridge: Blacksburg, Virginia Polytechnic Institute Department of Geological Sciences Memoir 1, p. 71-80.

Rodgers, John, 1968, The eastern edge of the North American continent during the Cambrian and Early Ordovician, in Zen, E-an, and others, eds., Studies of Appalachian geology -- northern and maritime: New York, Interscience Publishers, p. 141-149.

Rodgers, John, 1970, The tectonics of the Appalachians: New York, Wiley Interscience, 271 p.

Rodgers, John, 1972, Latest Precambrian (post-Grenville) rocks of the Appalachian region: American Journal of Science, v. 272, p. 507-520.

Rodgers, John, 1982, The life history of a mountain range -- the Appalachians, in Hsu, K.J., ed., Mountain building processes: London, Academic Press, p. 229-241.

Rogers, J.J.W., 1982, Criteria for recognizing environments of formation of volcanic suites; application of these criteria to volcanic suites in the Carolina slate belt, in Bearce, D.N., and others, eds., Tectonic studies in the Talladega and Carolina slate belts, southern Appalachian orogen: Geological Society of America Special Paper 191, p. 99-107.

Roper, P.J., and Dunn, D.E., 1971, Polymetamorphism of the Brevard zone and Blue Ridge of northwestern South Carolina (abs.): Geological Society of America Abstracts with Programs, v. 3, no. 7, p. 688.

Ross, C.R., II, and Bickford, M.E., 1980, The U-Pb age of zircons from the Elberton Granite, Piedmont of Georgia, in Stormer, J.C., Jr., and Whitney, J.A., eds., Geological, geochemical, and geophysical studies of the Elberton batholith, eastern Georgia: Georgia Geologic Survey Guidebook 19, p. 52-62.

Rowley, D.B., and Kidd, W.S.F., 1981, Stratigraphic relationships and detrital composition of the medial Ordovician flysch of western New England: implications for the tectonic evolution of the Taconic Orogeny: Journal of Geology, v. 89, p. 199-218.

Rozen, R.W., 1978, The geology of the Elberton East quadrangle, Georgia: Athens, University of Georgia, unpublished M.S. thesis, 110 p.

Rozen, R.W., 1981, The Middleton-Lowndesville cataclastic zone in the Elberton East quadrangle, Georgia, in Horton, J.W., Jr., and others, eds., Geological investigations of the Kings Mountain belt and adjacent areas in the Carolinas: Carolina Geological Society Field Trip Guidebook 1981, p. 174-180.

Russell, G.S., 1978, U-Pb, Rb-Sr, and K-Ar isotopic studies bearing on the tectonic development of the southernmost Appalachian orogen, Alabama: Tallahassee, Florida State University, unpublished Ph.D. dissertation, 197 p.

Russell, G.S., Russell, C.W., and Golden, B.K., 1984, The Taconic history of the northern Alabama Piedmont (abs.): Geological Society of America Abstracts with Programs, v. 16, no. 3, p. 191.

Safford, J.M., 1851, The Silurian basin of Middle Tennessee with notices of the strata surrounding it: American Journal of Science, 2nd series, v. 12, p. 352-361.

Salisbury, J.W., 1961, Geology and mineral resources of the northwest quarter of the Cohutta Mountain quadrangle: Georgia Geological Survey Bulletin 71, 61 p.

Salvador, Amos, 1985, Chronostratigraphic and geochronometric scales in COSUNA stratigraphic correlation charts of the United States: American Association of Petroleum Geologists Bulletin, v. 69, no. 2, p. 181-189.

Samson, S.L., Secor, D.T., Jr., Snoke, A.W., and Palmer, A.R., 1982, Geological implications of recently discovered Middle Cambrian trilobites in the Carolina slate belt (abs.): Geological Society of America Abstracts with Programs, v. 14, no. 7, p. 607.

Sanders, R.P., 1983, Major element chemistry of tonalitic and trondhjemitic rocks in the west Georgia Piedmont (abs.): Geological Society of America Abstracts with Programs, v. 15, no. 2, p. 46.

Sanders, R.P., Jeffers, L., and Reid, B.J., 1979, Petrology of eliptical calcareous pods in metagreywackes (abs.): Georgia Journal of Science, v. 37, no. 2, p. 88.

Schamel, Steven, and Bauer, David, 1980, Remobilized Grenville basement in the Pine Mountain window, in Wones, D.R., ed., The Caledonides in the U.S.A.: International Geological Correlations Program, project 27: Caledonide orogen: Blacksburg, Virginia Polytechnic Institute and State University Department of Geological Sciences Memoir 2, p. 313-316.

Schamel, Steven, Hanley, T.B., and Sears, J.W., 1980, Geology of the Pine Mountain Window and adjacent terranes in the Piedmont province of Alabama and Georgia: Geological Society of America, Field Trip Guidebook for 29th Annual Meeting of Southeastern Section, Birmingham, Alabama, 1980.

Sears, J.W., 1985, A model for the growth and detachment of a footwall duplex beneath the Piedmont-Blue Ridge allochthon, Alabama and Georgia (abs.): Geological Society of America Abstracts with Programs, v. 17, no. 2, p. 134.

Sears, J.W., and Cook, R.B., 1984, An overview of the Grenville basement complex of the Pine Mountain window, Alabama and Georgia, in Bartholomew, M.J., ed., The Grenville event in the Appalachians and related topics: Geological Society of America Special Paper 194, p. 281-287.

Sears, J.W., Cook, R.B., and Brown, D.E., 1981, Contrasts in tectonic style between the Inner Piedmont terrane and the Pine Mountain window: Alabama Geological Society, Guidebook 18th Annual Field Trip, p. 1-14.

Sears, J.W., Cook, R.B., Gilbert, O.E., Jr., Carrington, T.J., and Schamel, Steven, 1981, Stratigraphy and structure of the Pine Mountain window in Georgia and Alabama, in Wigley, P.B., ed., Latest thinking on the stratigraphy of selected areas in Georgia: Georgia Geologic Survey Information Circular 54-A, p. 41-53.

Secor, D.T., Jr., Samson, S.L., Snoke, A.W., and Palmer, A.R., 1983, Confirmation of the Carolina slate belt as an exotic terrane: Science, v. 221, p. 649-650.

Secor, D.T., Jr., and Snoke, A.W., 1978, Stratigraphy, structure, and plutonism in the central South Carolina Piedmont, in Snoke, A.W., ed., Geological investigations of the eastern Piedmont, southern Appalachians: South Carolina State Development Board, Division of Geology, Guidebook, Carolina Geological Society, p. 65-123.

Seiders, V.M., 1978, A chemically bimodal, calc-alkaline suite of volcanic rocks, Carolina slate belt, central North Carolina: Southeastern Geology, v. 19, p. 241-265.

Shapiro, Leonard, 1975, Rapid analysis of silicate, carbonate, and phosphate rocks--revised edition: U.S. Geological Survey Bulletin 1401, 76 p.

Sharp, W.E., and Hornig, C.A., 1981, The barite deposit at Kings Creek, South Carolina, in Horton, J.W., Jr., and others, eds., Geological investigations of the Kings Mountain belt and adjacent areas in the Carolinas: Carolina Geological Society Field Trip Guidebook 1981, p. 120-129.

Shaw, C.E., 1970, Age and stratigraphic relations of the Talladega Slate: evidence of pre-Middle Ordovician tectonism in central Alabama: Southeastern Geology, v. 11, no. 4, p. 253-268.

Shaw, C.E., 1973, Stratigraphy, structure, and tectonics of rocks adjacent to the Piedmont physiographic front in Talladega County, Alabama, in Carrington, T.J., ed., Talladega metamorphic front: Alabama Geological Society, Guidebook 11th Annual Field Trip, p. 56-65, 101-103.

Shaw, C.E., and Rodgers, John, 1963, Subdivisions of the Talladega Slate of Alabama (abs.): Geological Society of America Special Paper 87, p. 239-240.

Shaw, H.F., and Wasserburg, G.J., 1984, Isotopic constraints on the origin of Appalachian mafic complexes: American Journal of Science, v. 284, p. 319-349.

Shufflebarger, T.E., 1961, Notes on relationships of Piedmont metasedimentary rocks with emphasis on the Poor Mountain-Chauga River area, Oconee County, S.C.: South Carolina Development Board, Division of Geology, Geologic Notes, v. 5, p. 31-38.

Sibley, D.M., 1983, The structural fabric of the Rockmart Slate and its relation to the timing of orogenesis in the Valley and Ridge province of northwest Georgia: Auburn, Alabama, Auburn University, unpub. M.S. thesis, 121 p.

Sinha, A.K., Guy, Russell, Hund, Erik, and Tamburro, Edie, 1985, Thermal and tectonic evolution of the central and southern Appalachians: Evidence from distribution, age, and origin of granitic rocks (abs.): Geological Society of America Abstracts with Programs, v. 17, no. 7, p. 719.

Sinha, A.K., Higgins, M.W., Davis, G.H., Hart, S.R., and Kirk, W.S., 1970, The Glenarm Series and related rocks: Carnegie Institution of Washington Year Book, 1969-70, p. 412-413.

Sinha, A.K., and Zietz, Isidore, 1982, Geophysical and geochemical evidence for a Hercynian magmatic arc, Maryland to Georgia: Geology, v. 10, no. 11, p. 593-596.

Slack, J.F., 1982, Tourmaline in Appalachian-Caledonian massive sulfide deposits and its exploration significance: Institute of Mining and Metallurgy Transactions, Section B, v. 91, p. B81-B89.

Slater, W.R., 1982, Massive sulfide deposits of the Ducktown mining district, Tennessee, in Exploration for metallic resources in the southeast: Athens, University of Georgia, p. 91-99.

Slater, W.R., Misra, K.C., and Acker, C.P., II, 1985, Massive sulfide deposits of the Ducktown district, Tennessee, in Woodward, N.B., ed., Field trips in the southern Appalachians, field trips 1-5, 7: Knoxville, University of Tennessee, Department of Geological Sciences Studies in Geology 9, p. 171-190.

Sloan, Earl, 1908, Catalogue of mineral localities of South Carolina: South Carolina Geological Survey Bulletin 2, 4th Section, 505 p.

Smith, J.W., Wampler, J.M., and Green, M.A., 1969, Isotopic dating and metamorphic isograds of the crystalline rocks of Georgia: Georgia Geological Survey Bulletin 80, p. 121-139.

Smith, R.E., and Smith, S.E., 1976, Comments on the use of Ti, Zr, Y, Sr, K, P, and Nb in classification of basaltic magmas: Earth and Planetary Science Letters, v. 32, p. 114-120.

Smith, W.E., 1979, Pennsylvanian stratigraphy of Alabama, in Thomas, W.A., and others, The Mississippian and Pennsylvanian (Carboniferous) systems in the United States -- Alabama and Mississippi: U.S. Geological Survey Professional Paper 1110-I, p. I-23-I-36.

Smith, W.E., Neathery, T.L., and Drahovzal, J.A., 1971, Ordovician K-bentonites in Alabama, in Drahovzal, J.A., and Neathery, T.L., eds., The Middle and Upper Ordovician of the Alabama Appalachians: Alabama Geological Society, Guidebook 9th Annual Field Trip, p. 125-135.

Snoke, A.W., Secor, D.T., Jr., Bramlett, K.W., and Prowell, D.C., 1980, Geology of the eastern Piedmont fault system in South Carolina, in Frey, R.W., ed., Excursions in southeastern geology, v. I: Washington, D.C., American Geological Institute, p. 59-100.

St. Julien, Pierre, and Hubert, Claude, 1975, Evolution of the Taconian orogen in the Quebec Appalachians: American Journal of Science, v. 275-A, p. 337-362.

Stanley, R.S., and Ratcliffe, N.M., 1980, Accretionary collapse of the western margin of Iapetus in central New England during the Taconic orogeny (abs.): Geological Society of America Abstracts with Programs, v. 12, p. 85.

Stanton, R.L., 1976a, Petrochemical studies of the ore environment at Broken Hill, New South Wales: 1 - constitution of "banded iron formation": Transactions of the Institution of Mining and Metallurgy, section B, v. 85, p. B33-B-46.

Stanton, R.L., 1976b, Petrochemical studies of the ore environment at Broken Hill, New South Wales: 4 - environmental synthesis: Transactions of the Instution of Mining and Metallurgy, section B, v. 85, p. B221-B233.

Stevens, R.K., 1970, Cambro-Ordovician flysch sedimentation and tectonics in western Newfoundland and their possible bearing on a proto-Atlantic, in Lajoie, J., ed., Flysch sedimentology in North America: Geological Association of Canada Special Paper 7, p. 165-178.

Stevens, R.K., and Williams, Harold, 1973, The emplacement of the Humber Arm Allochthon, western Newfoundland (abs.): Geological Society of America Abstracts with Programs, v. 5, no. 2, p. 222.

Stieve, A.L., 1984, Petrologic variation of the granulites and related gneisses of Pine Mountain Terrane, Georgia: Atlanta, Emory University, unpublished M.S. thesis, 88 p.

Stonebreaker, J.D., and Harper, C.T., 1973, Potassium-argon geochronology of the Brevard zone (abs.): Geological Society of America Abstracts with Programs, v. 5, no. 5, p. 439.

Stose, G.W., and Stose, A.J., 1944, The Chilhowee Group and Ocoee Series of the southern Appalachians: American Journal of Science, v. 242, p. 367-390, 401-416.

Stose, G.W., and Stose, A.J., 1949, Ocoee Series of the southern Appalachians: Geological Society of America Bulletin, v. 60, p. 267-320.

Stose, A.J., and Stose, G.W., 1957, Geology and mineral resources of the Gossan Lead district and adjacent areas in Virginia: Virginia Division of Mineral Resources Bulletin 72, 233 p.

Stow, S.H., 1982, Igneous petrology of the Hillabee Greenstone, northern Alabama Piedmont, in Bearce, D.N., and others, eds., Tectonic studies in the Talladega and Carolina slate belts, southern Appalachian orogen: Geological Society of America Special Paper 191, p. 79-92.

Stow, S.H., Neilson, M.J., and Neathery, T.L., 1984, Petrography, geochemistry, and tectonic significance of the amphibolites of the Alabama Piedmont: American Journal of Science, v. 284, pl 416-436.

Stow, S.H., and Tull, J.F., 1982, Geology and geochemistry of the stratabound sulfide deposits of the Pyriton district, Alabama: Economic Geology, v. 77, p. 322-334.

Sun, Shen-Su, and Nesbitt, R.W., 1978, Geochemical regularities and genetic significance of ophiolitic basalts: Geology, V. 6, no. 11, p. 689-693.

Sun, Shen-Su, Nesbitt, R.W., and Sharaskin, A.Y., 1979, Geochemical characteristics of mid-ocean ridge basalts: Earth and Planetary Science Letters, v. 44, p. 119-138.

Sundelius, H.W., 1970, The Carolina slate belt, in Fisher, G.W., and others, eds., Studies of Appalachian geology -- central and southern: New York, Interscience Publishers, p. 351-367.

Sutley, D.E., 1977, A petrographic and paleoenvironmental study of the Jemison Chert, Chilton County, Alabama: Tuscaloosa, University of Alabama, unpublished M.S. thesis, 74 p.

Telle, W.R., 1981, Depositional setting of the diamictite facies of the Lay Dam Formation, Talladega slate belt, Chilton County, Alabama: Tuscaloosa, University of Alabama, unpublished M.S. thesis, 74 p.

Telle, W.R., Tull, J.F., and Russell, C.W., 1979, Tectonic significance of the bouldery facies of the Lay Dam Formation, Talladega slate belt, Chilton County, Alabama (abs.): Geological Society of America Abstracts with Programs, v. 11, no. 4, p. 215.

Thomas, W.A., 1979, Mississippian Stratigraphy of Alabama, in Thomas, W.A., and others, The Mississippian and Pennsylvanian (Carboniferous) systems in the United States -- Alabama and Mississippi: U.S. Geological Survey Professional Paper 1110-I, p. I-1-I-22.

Thomas, W.A., and Cramer, H.R., 1979, The Mississippian and Pennsylvanian (Carboniferous) systems in the United States -- Georgia: U.S. Geological Survey Professional Paper 1110-H, 37 p.

Thomas, W.A., and Drahovzal, J.A., 1973, Regional Paleozoic stratigraphy of Alabama, in Carrington, T.J., ed., Talladega metamorphic front: Alabama Geological Society, Guidebook 11th Annual Field Trip, p. 66-91.

Thomas, W.A., and Neathery, T.L., 1980, Tectonic framework of the Appalachian orogen in Alabama, in Frey, R.W., ed., Excursions in southeastern geology, v. II: Washington, D.C., American Geological Institute, p. 465-528.

Thomas, M.D., 1983, Tectonic significance of paired gravity anomalies in the southern and central Appalachians, in Hatcher, R.D., Jr., and others, eds., Contributions to the tectonics and geophysics of mountain chains: Geological Society of America Memoir 158, p. 113-124.

Thompson, A.M., 1971, Clastic-carbonate facies relationships and paleoenvironments in Upper Ordovician rocks of northeast Alabama, in Drahovzal, J.A., and Neathery, T.L., eds., The Middle and Upper Ordovician of the Alabama Appalachians: Alabama Geological Society Ninth Annual Field Trip Guidebook, p. 63-78.

Thompson, A.M., 1973, An algal bioherm in the Shady Formation near Oldfield, Alabama, in Carrington, T.J., ed., Talladega metamorphic front: Alabama Geological Society, Guidebook 11th Annual Field Trip, p. 92-100.

Tull, J.F., 1978, Structural development of the Alabama Piedmont northwest of the Brevard Zone: American Journal of Science, v. 278, p. 442-460.

Tull, J.F., 1979, Stratigraphic and structural relationships of the eastern Talladega slate belt of Alabama, in Tull, J.F., and Stow, S.H., eds., The Hillabee metavolcanic complex and associated rock sequences: Alabama Geological Society, Guidebook 17th Annual Field Trip, p. 3-13.

Tull, J.F., 1982, Stratigraphic framework of the Talladega slate belt, Alabama Appalachians, in Bearce, D.N., and others, eds., Tectonic studies in the Talladega and Carolina slate belts, southern Appalachian orogen: Geological Society of America Special Paper 191, p. 3-18.

Tull, J.F., 1984, Polyphase late Paleozoic deformation in the southeastern foreland and northwestern Piedmont of the Alabama Appalachians: Journal of Structural Geology, v. 6, no. 3, p. 223-234.

Tull, J.F., and Guthrie, G.M., 1983, Talladega belt/Blue Ridge belt stratigraphies -- can they be correlated? (abs.): Geological Society of America Abstract with Programs, v. 15, no. 2, p. 95.

Tull, J.F., and Stow, S.H., 1980a, The Hillabee Greenstone: a mafic volcanic complex in the Appalachian Piedmont of Alabama: Geological Society of America Bulletin, pt. 1, v/ 91, p. 27-36.

Tull, J.F., and Stow, S.H., 1980b, Structural and stratigraphic setting of arc volcanism in the Talladega slate belt in Alabama, in Frey, R.W., ed., Excursions in southeastern geology, v. II: Washington, D.C., American Geological Institute, p. 545-581.

Tull, J.F., and Stow, S.H., 1982, Geologic setting of the Hillabee metavolcanic complex and associated strata-bound sulfide deposits in the Appalachian Piedmont of Alabama: Economic Geology, v. 77, p. 312-321.

Tull, J.F., Stow, S.H., Long, Lamar, and Hayes-Davis, Bertram, 1978, The Hillabee Greenstone: stratigraphy, geochemistry, structure, mineralization and theories of origin: Tuscaloosa, University of Alabama Mineral Resources Institute, Research Report 1, 100 p.

Ulrich, E.O., 1911, Revision of the Paleozoic systems: Geological Society of America Bulletin, v. 22, p. 281-680.

Upadhyay, H.D., Dewey, J.F., and Neale, E.R.W., 1971, The Betts Cove ophiolite complex, Newfoundland: Appalachian oceanic crust and mantle: Proceedings of the Geologists Association of Canada, v. 24, no. 1, p. 27-34.

Van der Voo, Rob, 1983, A plate-tectonics model for the Paleozoic assembly of Pangea based on paleomagnetic data, in Hatcher, R.D., Jr., and others, eds., Contributions to the tectonics and geophysics of mountain chains: Geological Society of America Memoir 158, p. 19-23.

Van Horn, E.C., 1948, Talc deposits of the Murphy Marble belt: North Carolina Division of Mineral Resources Bulletin 56, 54 p.

Vincent, H.R., 1984, Geologic map of the Siloam Granite and vicinity, eastern Georgia: Georgia Geologic Survey Geologic Atlas 1, scale 1:48,000.

Waldbaum, D.R., 1971, Temperature changes associated with adiabatic decompression in geological processes: Nature, v. 232, p. 545-547.

Wallace, B.M., 1981, Petrography and chemistry of the Wahoo Creek Formation, Stone Mountain quadrangle, Georgia (abs.): Georgia Journal of Science, v. 39, no. 2, p. 71.

Watkins, J.S., 1971a, Sea Floor spreading -- crustal convergence moldel for the southern Appalachians (abs.): Geological Society of America Abstracts with Programs, Southeastern Section, v. 3, p. 357-358.

Watkins, J.S., 1971b, Evidence of pre-Mesozoic crustal convergence in the southern Appalachians (abs.): Geological Society of America Abstracts with Programs, v. 3, no. 7, p. 745.

Watkins, J.S., and Huggett, T., 1970, Evidence of middle Paleozoic sea floor spreading in the southern Appalachians (abs.): EOS, American Geophysical Union Transactions, v. 51, p. 824.

Webb, J.E., 1958, Reconnaissance geologic survey of parts of Polk and Haralson Counties, Georgia: Georgia Mineral Newsletter, v. XI, no. 1, p. 19-24.

Wenner, D.B., 1980, Oxygen isotope variations within the Elberton Granite pluton, in Stormer, J.C., Jr., and Whitney, J.A., eds., Geological, geochemical, and geophysical studies of the Elberton batholith, eastern Georgia: Georgia Geologic Survey Guidebook 19, p. 31-43.

Whisonant, R.C., 1970, Paleocurrents in basal Cambrian rocks in central Tennessee: Geological Society of America Bulletin, v. 81, p. 2781-2786.

Whisonant, R.C., 1974, Petrology of the Chilhowee Group (Cambrian and Cambrian?) in central, eastern, and southern Tennessee: Journal of Sedimentary Petrology, v. 44, p. 228-241.

White, J.S., 1981, Mineralogy of the Foote mine, Kings Mountain, North Carolina, in Horton, J.W., Jr., and others, eds., Geological investigations of the Kings

Mountain belt and adjacent areas in the Carolinas: Carolina Geological Society Field Trip Guidebook 1981, p. 39-48.
White, W.A., 1950, Blue Ridge front -- a fault scarp: Geological Society of America Bulletin, v. 71, p. 1309-1346.
Whitney, J.A., and Hess, J.R., 1980, Geochronology and cooling history of the Elberton Granite, in Stormer, J.C., Jr., and Whitney, J.A., eds., Geological, geochemical, and geophysical studies of the Elberton batholith, eastern Georgia: Georgia Geologic Survey Guidebook 19, p. 63-79.
Whitney, J.A., Paris, T.A., Carpenter, R.H., and Hartley, M.E., III, 1978, Volcanic evolution of the southern slate belt of Georgia and South Carolina: a primitive oceanic island arc: Journal of Geology, v. 86, p. 173-192.
Whitney, J.A., and Stormer, J.C., Jr., 1980, Road log for the 1980 Georgia Geological Society Field Trip, in Stormer, J.C., Jr., and Whitney, J.A., eds., Geological, geochemical, and geophysical studies of the Elberton batholith, eastern Georgia: Georgia Geologic Survey Guidebook 19, p. 108-134.
Williams, Harold, 1975, Structural succession, nomenclature, and interpretation of transported rocks in western Newfoundland: Canadian Journal of Earth Sciences, v. 12, p. 1874-1894.
Williams, Harold, (compiler), 1978, Tectonic lithofacies map of the Appalachian orogen: Memorial University of Newfoundland, Map no. 1, scale 1:1,000,000, Map no. 1a, scale 1:2,000,000.
Williams, Harold, 1979, Appalachian orogen in Canada: Canadian Journal of Earth Sciences, v. 16, no. 3, p. 792-807.
Williams, Harold, Kennedy, M.J., and Neale, E.R.W., 1972, The Appalachian structural province, in Price, R.A., and Douglass, R.J.W., eds., Variations in tectonic styles in Canada: Geologists Association of Canada Special Paper 11, p. 181-261.
Williams, Harold, and Hatcher, R.D., Jr., 1982, Suspect terranes and accretionary history of the Appalachian orogen: Geology, v. 10, no. 10, p. 530-536.
Williams, Harold, and Hatcher, R.D., Jr., 1983, Appalachian suspect terranes, in Hatcher, R.D., Jr., and others, eds., Contributions to the tectonics and geophysics of mountain chains: Geological Society of America Memoir 158, p. 33-53.
Williams, Harold, and Smyth, W.R., 1973, Metamorphic aureoles beneath ophiolite suites and Alpine peridotites: tectonic implications with west Newfoundland examples: American Journal of Science, v. 273, no. 7, p. 594-621.
Williams, Harold, and Stevens, R.K., 1974, The ancient continental margin of eastern North America, in Burke, C.A., and Drake, C.L., eds., The geology of continental margins: New York, Springer-Verlag, p. 781-796.
Williams, Harold, and Talkington, R.W., 1977, Distribution and tectonic setting of ophiolites and ophiolitic melanges in the Appalachian orogen, in Coleman, R.G., and Irwin, W.P., eds., North American ophiolites: Oregon Department of Geology and Mineral Industries Bulletin 95, p. 1-11.
Willis, Bailey, 1893, Mechanics of Appalachian structure: U.S. Geological Survey 13th Annual Report, p. 211-281.
Wilson, C.W., Jr., 1949, Pre-Chattanooga stratigraphy in central Tennessee: Tennessee Division of Geology Bulletin 56, 407 p.
Wilson, F.A., 1981, Geologic interpretation of geophysical data from the "Mecklenburg-Weddington" gabbro complex, southern Mecklenburg County, North Carolina, in Horton, J.W., Jr., and others, eds., Geological investigations of the Kings Mountain belt and adjacent areas in the Carolinas: Carolina Geological Society Field Trip Guidebook 1981, p. 28-38.
Windley, B.F., 1976, The evolving continents: New York, John Wiley & Sons, 385 p.

Wood, D.A., 1980, The application of a Th-Hf-Ta diagram to problems of tectonomagmatic classification and to establishing the nature of crustal contamination of basaltic lavas of the British Tertiary volcanic province: Earth and Planetary Science Letters, v. 50, no. 1, p. 11-30.

Wood, D.A., Joron, J.L., and Treuil, M., 1979, A reappraisal of the use of trace elements to classify and discriminate between magma series erupted in different tectonic settings: Earth and Planetary Science Letters, v. 45, no. 2, p. 326-336.

Wood, S.A., and Spera, F.J., 1984, Adiabatic decompression of aqueous solutions: Applications to hydrothermal fluid migration in the crust: Geology, v. 12, no. 12, p. 707-710.

Worthington, J.E., 1964, An exploration program for nickel in the southeastern United States: Economic Geology, v. 59, p. 97-109.

Zen, E-an, 1961, Stratigraphy and structure at the north end of the Taconic Range in west-central Vermont: Geological Society of America Bulletin, v. 72, p. 293-338.

Zen, E-an, 1967, Time and space relationships of the Taconic allochthon and autochthon: Geological Society of America Special Paper 97, 107 p.

Zen, E-an, 1968, Nature of the Ordovician orogeny in the Taconic area, in Zen, E-an, and others, eds., Studies of Appalachian geology -- northern and maritime: New York, Interscience Publishers, p. 129-139.

Zen, E-an, 1981, An alternative model for the development of the allochthonous southern Appalachian Piedmont: American Journal of Science, v. 281, p. 1153-1163.

Zen, E-an, 1983, Exotic terranes in the New England Appalachians - limits, candidates, and ages: A speculative essay, in Hatcher, R.D., Jr., and others, eds., Contributions to the tectonics and geophysics of mountain chains: Geological Society of America Memoir 158, p. 55-81.

APPENDIX A

The purpose of this appendix is to revise and adopt some of the stratigraphic nomenclature of the Appalachian orogen in Georgia and Alabama. Our purpose is to simplify stratigraphic nomenclature as much as possible by abandoning names where more than one name has been used for the same unit, or where one name has been used for two or more very different units, by using established names where possible rather than proposing new names (unless the established names are improper), and by naming as few new units as possible. For rules on stratigraphic nomenclature we adhere to the North American Stratigraphic Code (North American Commission on Stratigraphic Nomenclature, 1983). Following Salvadore (1985, p. 187) we use the term Precambrian preferentially over the term Proterozoic as "a general term for that part of the time scale that preceeded the Cambrian." Precambrian is recognized Worldwide, is generally understood by most geologists, and is in general use outside the U.S. Geological Survey.

Chickamauga terrane, Kingston, Clinchport, and Rome thrust sheets

The Chickamauga terrane and overlying Kingston, Clinchport, and Rome thrust sheets of the Rome-Kingston thrust stack are composed of sedimentary and metasedimentary rocks of the Valley and Ridge province and the Cumberland Plateau province.

Chilhowee Group

Mack (1980) proposed that the Chilhowee Group in Georgia and Alabama is made up of (lowest to highest): the Cochran Formation, a fluvial deposit composed of arkosic conglomerate, arkose, and discontinuous mudstone; the Nichols Formation, an offshore marine deposit composed of greenish-gray mudstone with minor siltstone and very fine sandstone; the Wilson Ridge Formation, a tidal flat deposit composed of interbedded, crossbedded orthoquartzite and ripple-laminated silty mudstone; and, the Weisner Formation a beach-barrier deposit composed of Crossbedded and horizontally laminated orthoquartzite, conglomerate, and minor mudstone. The formational names are well-documented, and are here adopted as defined by Mack (1980).

Conasauga Group

Hayes (1891, p. 143) used the name Conasauga Shale for "alternating beds of limestone and calcareous shale" exposed along the Conasauga River in northwest Georgia. Milici (1973, p. 11) elevated the name Conasauga to group status, and included in it (lowest to highest) the Pumpkin Valley Shale, Rutledge Limestone, Rogersville Shale, Maryville Limestone, Nolichucky Shale, and Maynardville Limestone. We here adopt the name Conasauga Group, for use in Georgia and Alabama, as defined by Milici (1973), but restrict the formations in it to those used by Chowns and McKinney (1980) and Carter and others (1983). Chowns and McKinney (1980) and Carter and others (1983) divided the Conasauga Group into (lowest to highest) the Honaker Dolomite (Rodgers, 1953), Rogersville Shale, Maryville Limestone, Nolichucky Shale, and Maynardville Limestone (see Milici, 1973). We here adopt these names, for use in Georgia and Alabama, as defined by Milici (1973) and Rodgers (1953), and as used by Chowns and McKinney (1980) and Carter and others (1983).

Chickamauga Group/Supergroup

The name Chickamauga Limestone was used by Hayes (1891, p. 143), from the valley of West Chickamauga Creek in northwestern Georgia, for all strata between the top of the Knox Group and the base of the Rockwood Formation of Hayes (1894), which probably included the Sequatchie Formation of present usage. The Sequatchie was named a separate formation by Ulrich, 1911).

The Stones River and Nashville Groups were named by Safford (1851) for exposures in central Tennessee. Following Milici (1969), Milici and Smith (1969) applied the nomenclature of Wilson (1949) to the Chickamauga type area in Georgia, retaining the Stones River and Nashville as group names, and elevating the name Chickamauga to supergroup status (table 5). As defined by Milici and Smith (1969), the Chickamauga Supergroup in Georgia is composed of: the lower Stones River Group, which consists of (lowest to highest) the Pond Spring Formation, Murfreesboro Limestone, Ridley Limestone, Lebanon Limestone, and Carters Limestone; and, the upper Nashville Group, which consists of (lowest to highest) the Hermitage Formation, Cannon Limestone, and Catheys Formation. All of the names are well-documented, and we here adopt them, for use in Georgia, as defined by Milici and Smith (1969).

In Alabama, where the section is much thinner, Drahovzal and Neathery (1971) proposed using the Stones River and Nashville as formations (1971, p. 7) "pending more detailed work." They used the name Chickamauga Group, and assigned to it (lowest to highest) the Stones River Formation, with its basal Attalla Chert Conglomerate Member, the Nashville Formation, the Inman Formation, and the Leipers Limestone. The names are well-documented, and we here adopt them for use in Alabama, as defined by Drahovzal and Neathery (1971).

Neathery (1986), Drahovzal and Neathery (1971), Chowns and McKinney (1980), and Chowns and Carter (1983), have shown that equivalent carbonate-clastic and clastic rocks belonging to the Greensport Formation and Colvin Mountain Sandstone named by Neathery (1986), as used by Drahovzal and Neathery (1971), should be assigned to the Chickamauga Group in Alabama and the Chickamauga Supergroup in Georgia (table 5). The names Greensport Formation and Colvin Mountain Sandstone are here adopted and assigned to the Chickamauga Group and Supergroup.

Bill Arp thrust sheet

The Bill Arp thrust sheet is composed of thick sections of clastic metasedimentary rocks that lack volcanogenic components, of generally thin and discontinuous carbonate units that cap the pile of clastic metasediments, of generally calcareous and pelitic units deposited unconformably upon the carbonate units, and of relatively rare Grenville basement upon which the clastic sediments were deposited.

Grenville basement rocks

Known Grenville basement in the Bill Arp thrust sheet crops out in three areas in the crystalline terrane of Georgia: (1) in structurally complex anticlinoria along the western flank of the Murphy synclinorium in northern Georgia; and (2) in the Pine Mountain anticlinorium in central and west-central Georgia, and east-central Alabama (fig. 1); and (3) around a complex structural feature in northeast Georgia that has been called the "Tullaluh Falls dome" (Hatcher, 1974), where it has been called the Wiley Gneiss by Hatcher (1974). Grenville basement has not yet been identified outside the Pine Mountain anticlinorium in Alabama, but it may be present in anticlinoria cored by the Bill Arp thrust sheet. We here assign all of the Grenville basement rocks in north Georgia to the Allatoona Complex and all of the basement rocks in the Pine Mountain anticlinorium to the Wacoochee Complex.

Allatoona Complex (named) - Corbin Gneiss (revised and adopted), Salem Church and Fort Mountain Gneisses (abandoned)

Rocks of the Grenville basement in northern Georgia are here assigned to the Allatoona Complex, named for exposures along the shores of Lake Allatoona, east of Cartersville (fig. 1; Crawford and Cressler, in Cressler and others, 1979; McConnell and Costello, 1984). McConnell and Costello (1984) suggested calling these rocks the Corbin Gneiss Complex to accentuate the lithologic variability of

what had previously been called the Corbin Granite (Hayes, 1901) or Corbin Gneiss (see Martin, 1974). Their suggestion was a good one, but they apparently included in their complex the basement schists that have been intruded by the plutonic rocks that had previously been called Corbin Gneiss. This inclusion is proper for the basement complex which must include the Grenville-age or older country rocks that have been intruded by the plutonic gneisses, but it allows confusion between the names Corbin Gneiss and Corbin Gneiss Complex. We therefore propose that the name Corbin Gneiss be retained for the metaplutonic rocks in the basement complex east and northeast of Cartersville, whereas we propose that the entire assemblage of rocks in the basement complex in northern Georgia be called the Allatoona Complex. We propose that the names Fort Mountain Gneiss (Furcron and others, 1947) and Salem Church Gneiss (Bayley, 1928; Dallmeyer, 1975) be abandoned, and the name Corbin Gneiss used for the Grenville-age gneisses near Fort Mountain and near Salem Church - these rocks are lithically identical, in the same stratigraphic position as, and the same age as the Corbin Gneiss. The entire basement complex in these areas is assigned to the Allatoona Complex.

The Allatoona Complex crops out over a relatively large area east and northeast of Cartersville, Georgia, where it occupies the core of one of the complex anticlinoria that occur on the western flank of the Murphy synclinorium (fig. 1). In that area the Complex consists of the Corbin Gneiss (~85-95%), a coarsely megacrystic (megacrysts are K-feldspar and are probably mostly metaphenocrysts) granitic gneiss (~90%) with a pyroxene-bearing phase of the gneiss (~10%) that Kesler (1950) called andesine-augite gneiss and Crawford and Cressler (in Cressler and others, 1979) mapped as "metagabbro," and older (country rock) metasedimentary schists, gneisses, and quartzites (~5-15%) that occur as xenoliths and roof pendants (see Costello, 1978; Crawford and Cressler, in Cressler and others, 1979) in the Corbin Gneiss. Corbin Gneiss also crops out in the Salem Church area to the northeast (fig. 1; Dallmeyer, 1975; McConnell and Costello, 1984).

The Allatoona Complex is directly and unconformably overlain by clastic metasedimentary rocks of the Pinelog Formation (Hayes, 1895; Hull and others, 1919; McConnell and Costello, 1984), which stratigraphically underlie the clastic metasedimentary sequences in the Great Smoky Group and Ellijay Group in the Murphy synclinorium. Hayes (1901, p. 406) recognized that the rocks of the Pinelog Formation (his Pinelog conglomerate) were derived from the Corbin Gneiss, stating: "This area of Corbin granite at one time probably formed an island, since it is surrounded, in part at least, by rocks derived from its own waste." Kesler (1950), however, discounted Hayes' observations and interpretations, stating (1950, p. 20):

> "Contact relations show that the gneisses are younger than the enclosing metasediments, and were therefore developed in post-Cambrian time. All evidence obtained in the present work indicates that the gneisses were formed by the alteration through igneous influence of large parts of the older rocks..."

Kesler (1950) suggested that Corbin and Salem Church Gneisses are Carboniferous. Crickmay (1936), Croft (1963), Hadley (1970), King (1970), and Hurst (1973) all considered the Corbin and Salem Church Gneisses to be Paleozoic intrusive plutons, whereas Fairley (1966, 1973) followed Hayes and considered these gneisses part of the basement upon which the overlying metasedimentary rocks were deposited.

The unconformity between the Corbin Gneiss and the Pinelog Formation has been documented by Costello (1978) and McConnell and Costello (1984). Basal conglomerates of the Pinelog Formation of McConnell and Costello (1980) locally contain pebbles and cobbles of Corbin Gneiss. Thus, at least the lower part of the clastic pile was derived from erosion of the Allatoona Complex. The Pinelog Formation is adopted and assigned to the Ocoee Supergroup.

The Allatoona Complex appears to be retrograded to the amphibolite facies from the granulite facies (Martin, 1974; Dallmeyer, 1975; McConnell and Costello, 1984). Field relations and radiometric ages (Odom and others, 1973; Dallmeyer, 1975; T.W. Stern, oral commun., 1985) indicate that the Corbin Gneiss is a Grenville-age plutonic rock, thereby indicating that the country rocks in the Allatoona Complex are even older (perhaps roughly the same age as the Sparks Schist of the Grenville basement Wacoochee Complex in the Pine Mountain anticlinorium, which they strongly resemble).

Another outcrop area of Allatoona Complex Grenville basement rocks is in the Fort Mountain area (Furcron and others, 1947; Needham, 1972; Russell, 1976; McConnell and Costello, 1984) in the Bill Arp thrust sheet just east of Chatsworth, Georgia (fig. 1). There the Fort Mountain Gneiss (complex), Corbin Granite, and Cohutta schist of Furcron and others (1947) represent the Allatoona Complex as recognized by McConnell and Costello (1984; their Corbin Gneiss Complex); the "Corbin Granite" and parts of the "Fort Mountain Gneiss" (abandoned) being Corbin Gneiss equivalents, and parts of the "Fort Mountain gneiss" being equivalent to the country rocks in the Allatoona Complex east and northeast of Cartersville. Furcron and others (1947) gave the name "Cohutta schist" to the small altered ultramafic bodies associated with the Allatoona Complex around Fort Mountain - this name is here abandoned following McConnell and Costello (1984).

Wacoochee Complex (adopted)

Bentley and Neathery (1970, p. 34) gave the name Wacoochee Complex to all of the rocks structurally beneath the Hollis Quartzite of the Pine Mountain Group in the Pine Mountain block. These rocks are now considered part of the Grenville basement. We here adopt the name Wacoochee Complex for the Grenville basement rocks in the Pine Mountain anticlinorium in Georgia and Alabama. It includes the Woodland Gneiss, the Cunningham Granite, and the Sparks Schist. The reasons for the assignment of the Sparks Schist to the Wacoochee Complex are given below in the section on the Pine Mountain Group. The Halawaka Schist of Bentley and others (1982) is considered equivalent to the Sparks Schist.

Great Smoky Group

The Great Smoky Group in the Bill Arp thrust sheet consists of the Frolona and Bill Arp Formations in the Austell-Frolona anticlinorium, the Ola and Kalves Creek Formations in the Ola anticlinorium, and the Richard Russell Gneiss and Copperhill, Wehutty, Hughes Gap, Hothouse, and Dean Formations in the Murphy synclinorium. The names Copperhill, Hughes Gap, Hothouse, and Dean Formations of Hurst (1955) are here adopted. The Wehutty Formation is assigned to the Great Smoky Group, and the other units are discussed below.

Frolona and Bill Arp Formations (adopted)

By the early 1970's, the work of Crawford and Medlin (1973, 1974; Medlin and Crawford, 1973) had shown that one of the dominant structures of the Piedmont in western Georgia and eastern Alabama is a large tight to isoclinal, steeply inclined, northwest-verging antiform which they considered anticlinal and named the Austell-Frolona anticlinorium (figs. 1 and 3). They established a stratigraphy for the area, in which they considered the section to be (from oldest to youngest) the Frolona Formation, Bill Arp Formation, Sandy Springs Sequence (now Sandy Springs Group), and an unnamed sequence of metavolcanic and metaplutonic rocks (now assigned to Paulding Volcanic-Plutonic Complex and Ropes Creek Metabasalt).

Crawford and Medlins' (1973, 1974; Medlin and Crawford, 1973) stratigraphic sequence and the anticlinal nature of the Austell-Frolona fold were challenged by Abrams and McConnell (1981; McConnell and Abrams, 1984). They proposed that the

Austell-Frolona fold is an antiformal syncline and that the previously established stratigraphic sequence is mostly up-side-down, with the metavolcanic sequence (their New Georgia Group) the oldest unit, followed by the Sandy Springs Group, and with the Bill Arp Formation at the top of the section. Abrams and McConnell (1981, p. 63) stated:

> "Crawford and Medlin interpreted the Austell-Frolona as an antiform which was affected by a single fold event and placed their Frolona formation in the core of the fold as the oldest unit, stratigraphically underlying the Bill Arp Formation. Based on our interpretation of stratigraphic relationships and multiple folding within the Austell-Frolona, we believe it represents a second generation, overturned syncline. The Andy Mountain Formation (our Frolona formation equivalent) is still interpreted to be older than the Bill Arp Formation. While all facing criteria have been destroyed by metamorphism and multiple deformation, the gradual transition from a predominantly metavolcanic sequence (New Georgia Group) upward into a predominantly metasedimentary sequence (Roosterville group) supports this structural interpretation."

We don't see why a "gradual transition" from a predominately metavolcanic sequence to a predominately metasedimentary sequence would support an inversion of the sequences. Nevertheless, our detailed mapping of the Atlanta 1° x 30' quadrangle (Higgins, Atkins, and T.J. Crawford, unpublished), which includes the area described by Abrams and McConnell (1981; McConnell and Abrams, 1984), has shown that the stratigraphy of the area is partly a tectonostratigraphy, that graded bedding is widespread and well-preserved in the Bill Arp Formation, and that these facing criteria clearly show that the Austell-Frolona fold (though complex) is an anticlinorium.

The Austell-Frolona anticlinorium (fig. 1) extends from west of Roanoke, Alabama, to near Austell, Georgia (Crawford and Medlin, 1973, 1974; Medlin and Crawford, 1973). From near Roanoke, Alabama, to a few kilometers northwest of Whitesburg, Georgia (fig. 1), the anticlinorium is cored by a thick assemblage (>1500 meters) of clastic metasedimentary rocks, without volcanogenic components, that Crawford and Medlin (1974) named the Frolona Formation for characteristic exposures along secondary roads south and southwest of the community of Frolona, Heard County, Georgia, and along Hillabahatchee Creek northeast of Frolona, in the Frolona, Georgia 7 1/2'quadrangle; all of these sections are here designated a composite type section, and we propose formal acceptance of the Frolona Formation as defined by Crawford and Medlin (1974). Crawford and Medlin (1974, p. 1-9) defined the Frolona as follows:

> "The oldest rocks in the stratigraphic sequence in this part of the western Georgia-eastern Alabama Piedmont are those comprising the Frolona. This unit is named for the community of Frolona, Heard County, Georgia, where the lithologies are very well developed and exposed. The rocks comprising this unit occupy parts of Carroll and Heard Counties, Georgia and part of Randolph County, Alabama. They have a general northeast strike and compose the core of the Austell-Frolona Anticlinorium which has a length of more than 80 miles (128 km) in the western Georgia-eastern Alabama Piedmont. The thickness of the Frolona is estimated to be approximately 5000 feet (1525 m). It consists of the following rock types, interlayered: graphitic staurolite-kyanite-garnet-feldspar-quartz-muscovite schist, nongraphitic mica schist, feldspathic micaceous quartzite, clean quartzite, and quartz-pebble metaconglomerate.

The quartzites are fine to coarse grained, commonly feldspathic and micaceous. Layers of quartz-pebble metaconglomerate contain elongate pebbles as large as 8 x 20 mm in a quartz-feldspar-mica matrix."

We here assign the Frolona Formation to the Great Smoky Group of the Ocoee Supergroup (table 1).

Overlying the Frolona Formation is a thick sequence (>2700 meters) of rhythmically interbedded quartz-muscovite-biotite schist and muscovite-biotite-quartz-feldspar metagraywackes that Crawford and Medlin (1974, p. 9) named the Bill Arp Formation for characteristic exposures along secondary roads west and south of the community of Bill Arp and along the Dog River southwest of Bill Arp, in the Winston, Georgia 7 1/2' quadrangle; these sections are here designated a composite type section, and we here propose formal acceptance of the Bill Arp Formation as defined by Crawford and Medlin (1974).

Crawford and Medlin (1974, p. 1-9) defined the Bill Arp Formation as follows:

"Overlying the Frolona is a unit herein designated the Bill Arp. The unit is named for the community of Bill Arp, Douglas County, Georgia, where it is well exposed. The Bill Arp is the most extensive unit in this part of the western Georgia-eastern Alabama Piedmont. From Douglas County it extends southwestward through Carroll and Heard Counties, Georgia and into Randolph County, Alabama. Over most of this outcrop distance it is overturned to the northwest except in Douglas County, Georgia, where it is exposed on the nose of the northeasterly plunging Austell-Frolona Anticlinorium which is upright and open in this area. The unit is approximately 9000 feet (2745 m) thick. It consists of several rock types: quartz-muscovite-biotite schist, with some layers composed almost entirely of mica, alternating with muscovite-biotite-quartz-feldspar geniss (sic) and schist, sericite schist, and micaceous quartzite; quartzose-feldspathic layers are dominant. Mafic layers are rare, thin and discontinuous where present. Porphyroblastic mica cuts across schistosity and layering, and fractures are filled with coarse mica. Garnets are scarce, small where present. Thin layers of sericite schist contain abundant finely disseminated magnetite and ilmenite; coarse ilmenite is associated with vein quartz."

McConnell and Abrams (1984) assigned the Bill Arp Formation to the top of the Sandy Springs Group. Because the graded bedding in the Bill Arp Formation shows that McConnell and Abrams' (1984) stratigraphic section is inverted, and that the Bill Arp is at the bottom of the stratigraphic section (tectonostratigraphic section) we here assign the Bill Arp Formation to the Great Smoky Group of the Ocoee Supergroup. It is structurally several thrust sheets below the Sandy Springs Group.

Ola and Kalves Creek Formations (named)

About 50 kilometers southeast of the Austell-Frolona anticlinorium, the Bill Arp thrust sheet is again exposed in the Ola anticlinorium (figs. 1 and 3), where it is composed of a thick sequence (>2,000 meters) of clastic metasedimentary rocks that lack volcanogenic components. The lower unit in the Ola antiform is a sequence of medium- to coarse-grained schists with lensoidal units of biotite-plagioclase gneiss (metagraywacke or metasiltstone), here named the Ola Formation for characteristic outcrops in the Ola, Georgia 7 1/2' quadrangle. The type section of the Ola is here designated as the section exposed along Turner Church

Road between Georgia Highway 20 and Ola Road in the Ola, Georgia 7 1/2' quadrangle (fig. 3; this section also contains the type section of the Kalves Creek Formation).

Infolded with the Ola Formation in the Ola antiform is a unit composed of Ola lithologies, but with significant amounts of white- to yellow-white weathering, spindly, graphite-sillimanite schist (graphite in tiny blebs and flakes on the surfaces of fibrous sillimanite), here named the Kalves Creek Formation for characteristic exposures along Turner Church Road between Kalves Creek and Airline Road in the Ola, Georgia 7 1/2' quadrangle; these outcrops are here designated the type section. The Kalves Creek is never seen fresh except in drill core. In drill core the Kalves Creek has blebs of pyrite that make up as much as 10 percent of the rock.

We here assign the Ola and Kalves Creek Formations to the Great Smoky Group of the Ocoee Supergroup. The Kalves Creek Formation is a lithic match of the Wehutty Formation in the Murphy synclinorium, of part of the Frolona Formation in the Austell-Frolona anticlinorium, and of the Manchester schist in the Pine Mountain anticlinorium (table 3); all these units probably represent the same depositional environments, even though they may have been deposited in separate Ocoee basins.

Richard Russell Gneiss (revised)

The Richard Russell Formation (Gillon, 1982; Nelson and Gillon, 1985) was named for exposures along the Richard Russell Scenic Highway (Georgia Highway 348) in the Cowrock, Georgia 7 $^{1}/_{2}$ min. quadrangle. However, our mapping indicates that the Richard Russell should be restricted to the massive, but highly fractured biotite gneiss with minor amounts of biotite schist (as in the type section), and should not include the schist-amphibolite-gneiss unit west of the gneiss unit which is the Zebulon Formation (fig. 1). Because gneiss makes up more than 90 percent of the unit, we here modify the formations name to the Richard Russell Gneiss. We assign it to the Great Smoky Group. However, because the Richard Russell resides in a separate thrust slice from the other Great Smoky units in north Georgia, it is unknown exactly where it fits in the stratigraphic sequence. Our mapping has also shown that the amphibolite units that both Gillon (1982) and Nelson (1982) assigned to the Richard Russell belong to the Ropes Creek and Soapstone Ridge thrust sheets; they rest in thrust contact upon the Richard Russell. As far as we know the Richard Russell Gneiss is present in Georgia only in the area shown in figure 1.

In most outcrops the Richard Russell Gneiss lacks bedding or compositional layering because of transposition along closely spaced S-surfaces. Another feature of the Richard Russell is that it underlies much of the highest mountainous terrain in the crystalline terrane of Georgia; we interpret this as due to the highly fractured nature of the gneiss rather than to resistance to weathering and erosion. Meteoric water tends to penetrate through the gneiss to emerge as springs at the base of the formation rather than weathering and eroding it.

Pine Mountain Group (revised)

The Pine Mountain Group was traditionally considered to be composed of (lower to upper) the Sparks Schist, Hollis Quartzite, Manchester Schist and Chewacla Marble (Adams, 1926; Hewett and Crickmay, 1937; Crickmay, 1952; Clarke, 1952). Bentley and Neathery (1970 p. 35) proposed changing the name of the Hollis Quartzite to Hollis Metaorthoquartzite to "avoid confusion with nonmetamorphic sandstones." They also did not consider the Sparks Schist to be part of the Pine Mountain Group. More recently, Sears and others (1981) considered the Pine Mountain Group to consist of the Sparks Schist, Hollis Quartzite, and the Manchester Formation, which they divided into a (lower) Chewacla Schist Member and an upper Chewacla Marble Member. Our study indicates that the Sparks Schist does

not belong with the Pine Mountain Group but instead belongs to the Grenville basement. What has been mapped as Sparks Schist in the past is two different schists, one derived from shearing of granulitic basement gneisses (fig. 63), and the other a pelitic schist that has been intruded by the gneisses. We here reinstate the name Sparks Schist and remove it from the Pine Mountain Group; we abandon the name Sparks Formation. We restrict the Sparks Schist to the pelitic schists in the Wacoochee Complex of Grenville basement. We see no useful purpose in calling the Hollis a "metaorthoquartzite," and retain the name Hollis Quartzite. Our mapping shows that the Manchester is composed of two mappable formations, both depositional equivalents of formations in the Great Smoky Group, but the use of the name Chewacla for two different members of the Manchester (Sears and others, 1981) is improper (North American Commission on Stratigraphic Nomenclature, 1983) We propose that the name Manchester Schist be used for the lowermost unit of graphitic and sillimanitic schists, with lesser amounts of thin metagraywacke beds near its top, and propose the name Mountain Creek Formation for interbedded pelitic schist and graywacke that is well exposed around the valley of Mountain Creek in the Pine Mountain Southwest, Georgia 7 1/2 min. quadrangle. The type section is designated as the roadcuts along the paved road running southeast from Smiths Crossroads, from Mountain Creek to approximately 1.5 kilometers southeast of Mountain Creek. The Mountain Creek Formation is lithologically identical to the Bill Arp Formation described above. The Chewacla Marble is discontinuous and poorly exposed (except in one quarry near Chewacla State Park near Auburn, Alabama), but it appears to occur at the same stratigraphic horizon, and for short distances at least it is a mappable unit. Moreover, because of the scarcity of carbonate rocks in the crystalline terrane of Georgia and Alabama and because of the importance of the Chewacla to paleogeographic and paleotectonic interpretations, we believe it should be a formation, as did Prouty (1918), Adams (1926, 1930, 1933), and Bentley and Neathery (1970), and here restore the name Chewacla Marble to formational rank. We assign the Pine Mountain Group to the Ocoee Supergroup.

Ellijay Group and Blue Ridge Group (named), Murphy Group (abandoned)

The axial area of the Murphy synclinorium (fig. 1) in northern Georgia (Murphy syncline) is occupied by a sequence of rocks that has been called the "Murphy Belt Group" (Hurst, 1955; Mohr, 1973; Costello and others, 1982) or the "Murphy Group" (Hatcher, 1972; Dallmeyer and others, 1978). The Murphy Belt Group or Murphy Group has generally been considered to be composed of (in ascending order) the Nantahala Formation, Tusquitee Quartzite, Brasstown Formation, Murphy Marble, Andrews Formation, Nottely Quartzite, and Mineral Bluff Formation. Because evidence indicates that there is an unconformity above the Murphy Marble, we propose to separate the Murphy Belt Group or Murphy Group into two groups with the dividing line at the unconformity above the Murphy Marble. We propose the name Ellijay Group for the lower rocks including the Nantahala Formation, Tusquitee Quartzite, Brasstown Formation, and Murphy Marble. The group is named for the area around the town of Ellijay, Georgia. We propose the name Blue Ridge Group for rocks above the Murphy Marble, and assign to it the Andrews Formation, Nottely Quartzite, and Mineral Bluff Formation; the group is here named for the area around the city of Blue Ridge, Georgia, in the axial area of the Murphy syncline (fig. 1). The name Murphy Belt Group is abandoned because there is no geographic locality named Murphy Belt. The name Murphy Group is here abandoned for the following reasons. When a unit is divided into two units of the same rank the original name should not be used for either of the divisions because of the possibility of later misunderstanding of which definition is being used. Also, the same name should not be applied both to a unit as a whole and to a part of it. Murphy Marble is the older name and has priority (North American Commission on Stratigraphic Nomenclature, 1983).

Zebulon thrust sheet

The Zebulon thrust sheet is composed of intimate mixtures of metasedimentary rocks, metavolcanic rocks, and metavolcanogenic sediments. The only unit formally named here is the Zebulon Formation which comprises most of the sheet. The Senoia Formation (Higgins and Atkins, 1981) is demoted from a formation to a member of the Zebulon Formation.

Zebulon Formation (named)

Through much of Georgia and Alabama the Zebulon thrust sheet is composed mostly of a thick (probably >3,000 meters) assemblage of intercalated generally pink- to purple-weathering schists (commonly with abundant aluminosilicate minerals and garnet), and ocher-weathering hornblende-plagioclase amphibolites, with lesser amounts of a wide variety of biotite-plagioclase gneisses and granitic gneisses, which we here name the Zebulon Formation for characteristic outcrops in the Zebulon, Georgia 7 1/2' quadrangle. The type section is designated as the roadcuts along U.S. Highway 19 from Zebulon, Georgia, in the Zebulon 7 1/2' quadrangle to Wasp Creek in the Griffin South, Georgia 7 1/2' quadrangle. The name Zebulon Formation has already been used in Alabama by Sears and others (1981; based on our oral communication with them) and Stow and others (1984; following Sears and others, 1981). Some of the rocks of the Zebulon Formation were assigned by McConnell and Abrams (1984) to their Univeter Formation, which is abandoned in this paper.

Senoia Member of the Zebulon Formation (revised)

In its uppermost parts the Zebulon Formation has thin (everywhere less than a meter thick, and generally less than ~30 cm thick) beds of gondite (spessartine quartzite) and magnetite-bearing gondite, interpreted as metamorphosed volcanogenic chemical sediments. Higgins and Atkins (1981) named this gondite-bearing interval the Senoia Formation, but it has not been mapped separately from the Zebulon Formation in many areas. We here demote the Senoia from a formation to a member of the Zebulon Formation.

Atlanta thrust sheet

The Atlanta thrust sheet is a composite sheet made up of two thrust slices, the (lower) Stonewall slice and the (upper) Clarkston slice. The Stonewall slice is composed of the Stonewall Formation and the Clarkston slice is composed of (in ascending structural order) the Ison Branch and Barrow Hill Formations, the Clarkston Formation with its Fairburn Member, and the Big Cotton Indian Formation.

Higgins and Atkins (1981) named 12 formations in the Atlanta area which they included in the Atlanta Group. That was before the tectonostratigraphic nature of many of the units was recognized. Further work has shown that the Senoia Formation should be a member of the Zebulon Formation in the Zebulon thrust sheet. The Inman Yard Formation is now known to be Clairmont melange belonging to the Clairmont Formation in the Clairmont thrust sheet, so the name Inman Yard Formation is here abandoned. The Camp Creek and Promised Land Formations are now known to be the same formations. The type locality at Promised Land (Higgins and Atkins, 1981) is better than the type localilty at Camp Creek, so the name Camp Creek Formation is here abandoned. The Hannah Member of the Promised Land Formation is now known to be a mylonite schist along the Promised Land thrust fault at the base of the Promised Land thrust sheet, so the name Hannah Member is here abandoned. The Tar Creek Member of the Clarkston Formation is identical with Clarkston Formation undivided, so the name Tar Creek Member is here abandoned. The Intrenchment Creek Quartzite is part of what we name below the Barrow Hill Formation, so we here abandon the name Intrenchment Creek Quartzite. The name Atlanta Group is here

abandoned. Of the twelve formations of the former Atlanta Group, the Wolf Creek, Promised Land, Clairmont, Wahoo Creek, Stonewall, Clarkston, and Big Cotton Indian Formations, and Norcross Gneiss remain in good usage; the Senoia Formation is reduced to the Senoia Member of the Zebulon Formation; and the Camp Creek and Intrenchment Creek Formations, the Hannah Member of the Promised Land Formation, and the Tar Creek Member of the Clarkston Formation are abandoned. The new units proposed here are the Ison Branch and Barrow Hill Formations.

McConnell and Abrams (1984, p. 42-43) have recently proposed that the "stratigraphic" sequence in the Atlanta Group (abandoned) is inverted from that proposed by Higgins and Atkins (1981). They propose correlation of the Big Cotton Indian Formation, Intrenchment Creek Quartzite (abandoned), and Camp Creek Formation (abandoned) with their New Georgia Group (abandoned), correlation of the Clarkston Formation, Stonewall Formation, Wahoo Creek Formation, Clairmont Formation (Clairmont melange including former Inman Yard Formation), Senoia Formation (now a member of the Zebulon Formation), Wolf Creek Formation, Norcross Gneiss, Inman Yard Formation (abandoned), and Promised Land Formation with their "Powers Ferry Formation undifferentiated", and correlation of the Lanier Mountain Quartzite Member (abandoned) of the Snellville Formation (abandoned) with the Chattahoochee Palisades Quartzite of the Sandy Springs Group and of the Norris Lake Schist Member (abandoned) of the Snellville Formation (abandoned) with the Factory Shoals Formation of the Sandy Springs Group. Their correlations and inversion of the sequence in the Newnan-Tucker synform are based entirely on similarities between the gondite in the Barrow Hill Formation (formerly Intrenchment Creek Quartzite) and some parts of iron formations in their New Georgia Group (abandoned; consists of 3 different thrust sheets - see below), similarities between the Big Cotton Indian Formation and the part of the Sandy Springs Group that they placed in their New Georgia Group, and what they considered similarities between the Camp Creek Formation (abandoned) and parts of their New Georgia Group. Rocks of the former Camp Creek Formation (now Promised Land Formation) and Intrenchment Creek Quartzite (now Barrow Hill Formation) do not even bear a lithologic resemblance to the Ropes Creek Formation, Sandy Springs Group, and Paulding Volcanic-Plutonic Complex which Abrams and McConnell (1981; McConnell and Abrams, 1984) lumped into their New Georgia Group (abandoned). We (Higgins and others, 1984; this paper) have given evidence that the rocks that Higgins and Atkins (1981) assigned to the Atlanta Group (abandoned) are not found northwest of the Brevard Zone. In addition, because graded bedding in the Bill Arp Formation shows that Abrams and McConnell's (1981) and McConnell and Abrams'(1984) interpretation of the stratigraphic sequence northwest of the Brevard Zone is inverted, their proposed inversion of the sequence (chiefly a tectonostratigraphic sequence) in the Newnan-Tucker synform is invalid.

Ison Branch and Barrow Hill Formations (named)

The Ison Branch Formation, at the base of the Clarkston slice in the Atlanta thrust sheet (figs. 2 and 3) is here named for the large roadcut in saprolite along Hill Street just north of the juncture of Hill Street with U.S. Highway 41/19 Business, on the north side of Ison Branch, in the Griffin South 7 1/2' quadrangle; this roadcut is also designated the type section. The Ison Branch is a relatively thin unit (at most a few hundred meters are preserved) of metamorphosed, finely laminated, graphitic, calcareous, and pyritic felsic tuff that is seen fresh only in drill core or where very deep excavations have been blasted. It weathers to a very distinctive, finely laminated, nearly white, spongy saprolite (fig. 18) that is easily mapped. Locally it shows chaotic folding (fig. 19) that is interpreted to be soft-sediment deformation.

Structurally, and probably also stratigraphically above the Ison Branch Formation is a unit of intercalated blocky, sooty weathering gondite (spessartine

quartzite), pink- to purple-weathering garnet-sillimanite-biotite-muscovite schist, and ocher-weathering hornblende-plagioclase amphibolite that we here name the Barrow Hill Formation for exposures along the three roads that cut across Barrow Hill in the Orchard Hill, Georgia 7 1/2' quadrangle; these exposures are also designated a composite type section. The Barrow Hill apparently grades upward into the Clarkston Formation.

Sandy Springs thrust sheet

The Sandy Springs thrust sheet is composed of the Sandy Springs Group, which consists of (ascending order) the Powers Ferry Formation, Chattahoochee Palisades Quartzite, and Factory Shoals Formation (Higgins and McConnell, 1978). Rottenwood Creek Quartzite, included by Higgins and McConnell (1978) in the Sandy Springs Group was abandoned by Higgins and others (1984). In this paper we abandon the names (of Higgins and Atkins, 1981) Snellville Formation and its Lanier Mountain Quartzite Member, now shown to be the Chattahoochee Palisades Quartzite, and its Norris Lake Schist Member, now shown to be the Powers Ferry Formation, the Andy Mountain Formation of Abrams and McConnell (1981; McConnell and Abrams, 1984) and the Dog River Formation of McConnell and Abrams (1984). McConnell and Abrams (1984, p. 28-29) proposed changing Bayley's 1928 Canton schist to Canton Formation and assigned it to their New Georgia Group (abandoned). We propose reinstatement of the Canton Schist and assign it to the Ropes Creek Metabasalt.

Dog River Formation (abandoned)

McConnell and Abrams (1984, p. 38) proposed the name Dog River Formation for a sequence of metagraywacke, schist, and amphibolite with "thin (1-3 in) layers of banded iron formation." They stated that "The presence of this banded iron formation and the lithologic similarity of this unit to upper parts of the underlying New Georgia Group suggest that the contact with the New Georgia Group is gradational and represents a gradual waning of volcanism in this area." The graded bedding in the Bill Arp Formation indicates that the stratigraphic sequence proposed by McConnell and Abrams (1984) is inverted, and our work shows that the rocks they named the New Georgia Group belong to three different thrust sheets (Sandy Springs, Paulding, Ropes Creek). Thin quartzites containing minor amounts of magnetite are present in many outcrops of the Powers Ferry Formation (Higgins, 1965), and this caused McConnell and Abrams (1984) to set aside part of the Powers Ferry around the Dog River southeast of Villa Rica as the "Dog River Formation." Because these rocks clearly belong to the Powers Ferry Formation, the Dog River Formation is here abandoned.

Andy Mountain Formation (abandoned)
and Canton Schist (revised)

Abrams and McConnell (1981 p. 63-64; McConnell and Abrams, 1984) proposed the name Andy Mountain Formation for a unit of graphitic schists, garnetiferous schists, and quartzite in western Georgia northwest of the Brevard Zone. Part of this unit is lithically identical with the Canton Schist of Bayley (1928). McConnell and Abrams (1984, p. 28-29) proposed changing the Canton Schist to the Canton Formation because of the quartzite and graphitic and garnetiferous schists in the unit. Our work shows that part of the Andy Mountain Formation of Abrams and McConnell (1981; McConnell and Abrams, 1984) is the same unit as the Canton Schist of Bayley (1928) and Canton Formation of McConnell and Abrams (1984), and part is the Chattahoochee Palisades Quartzite of the Sandy Springs Group. Because Abrams and McConnell's Andy Mountain Formation belongs to two separate units we here abandon the Andy Mountain Formation of Abrams and McConnell (1981; McConnell and

Abrams (1984). Contrary to McConnell and Abrams' (1984, p. 29) statement "that the term Canton 'schist' as defined by Bayley (1928) is too restrictive...", Bayley's (1928, p. 43-46) detailed description of the Canton Schist includes all of the rock types in the unit in the Canton, Georgia, area and most of the rock types in the unit to the northeast and southwest. Furthermore, the unit is composed mostly of schists. Therefore, we propose reinstatement of Bayley's (1928) lithic term Canton Schist. The Canton Schist is interpreted as a metamorphosed assemblage of pelagic sediments and seafloor hydrothermal volcanogenic alteration zone deposits. It belongs in the Ropes Creek Metabasalt, and is here considered a member of the Ropes Creek.

Tallulah Falls Formation (abandoned)

Hatcher (1971, p. 9-10) proposed the name Tallulah Falls Formation for rocks of the Sandy Springs Group in northeast Georgia. Galpin (1915) had used the name Tallulah Falls Quartzite for the major quartzite unit in the area; he apparently had a section along the old Tallulah Falls Railway (1915, p. 119) in mind for the type locality and type section. Hatcher defined four members of his Tallulah Falls Formation (1971, p. 11-12), but he failed to give type localities for the members, or to formally designate either Tallulah Falls, the old Tallulah Falls Railway, or the city of Tallulah Falls as the type locality for the formation. No type sections were given for any of the units. Hatcher (1969) had earlier included the units in his "Whetstone Group." Hatcher (1974, p. 9) stated of his Tallulah Falls Formation: "This formation name was proposed to raise the name Tallulah Falls to group status..." Naming a unit a formation cannot raise its name to group status. In light of the lack of designated type localities or sections, confusion over groups versus formations, the fact that the units were never properly named, and the fact that the rocks belong to the Sandy Springs Group (Higgins, 1966; Higgins and McConnell, 1978), we here abandon the name Tallulah Falls Formation. The rocks Hatcher (1971) named Tallulah Falls Formation belong to the Powers Ferry Formation, Chattahoochee Palisades Quartzite, and Factory Shoals Formation of the Sandy Springs Group in the Sandy Springs thrust sheet.

Paulding thrust sheet

The Paulding thrust sheet is composed entirely of the Paulding Volcanic-Plutonic Complex (named below). Rocks of the Paulding Complex have been given various names in Alabama (Bentley and Neathery, 1970; Neathery, 1975; Tull and others, 1978; Stow, 1982; Stow and others, 1984), including the Waresville Amphibolite, a small part of the Ketchepedrakee Amphibolite, and the lower part of the Hillabee greenstone. We include these rocks in the Paulding Volcanic-Plutonic Complex, and suggest that the name Ketchepedrakee Amphibolite should be abandoned, but may be reserved for local usage. In Georgia, part of the Waresville Amphibolite of Bentley and Neathery (1970), part of the Pumpkinvine Creek Formation of McConnell (1980), and part of the New Georgia Group of Abrams and McConnell (1981) and McConnell and Abrams (1984) are included in the Paulding Volcanic-Plutonic Complex in the Paulding thrust sheet. In this paper, we abandon the names Waresville Amphibolite, Pumpkinvine Creek Formation, and New Georgia Group.

Paulding Volcanic-Plutonic Complex (named)

The Paulding Volcanic-Plutonic Complex is here named for exposures in Paulding County, Georgia, where thick sections of these rocks are exposed. The type section is designated as the section along the unnamed dirt road that runs south and southwest from Georgia Highway 120 in the northeast corner of the New Georgia, Georgia 7 1/2'quadrangle to the first dirt road to the west and along that east-west road to its intersection with a road running north and southwest to the Ropes Creek thrust fault at the base of the Ropes Creek Metabasalt about 320 meters west

of the cemetary on the south side of the road (fig. 64). The Paulding Volcanic-Plutonic Complex is made up of light-green-weathering, epidote-rich, generally chloritic, green or blue-green hornblende- or (and) actinolite-plagioclase amphibolites (about 50-60 percent) intimately interlayered with light-gray to nearly white, amphibole-bearing granofels and biotite-bearing gneisses (metamorphosed felsic and intermediate tuffs - about 20-30 percent). Dikes, sills, and small plutons of K-feldspar-poor granitic and K-feldspar bearing granitic rocks are ubiquitous and numerous (about 15-20 percent), and pods of epidosite are common. Thin layers and lenses of vermiculitic mica (not included in the percentages) are locally present, but their protolith is unknown. A distinctive siliceous and spongy "hardpan" is generally found above the rocks in the Paulding sheet. The Paulding is essentially an all-igneous unit, devoid of clastic metasedimentary rocks, although metamorphosed epiclastic sedimentary rocks are present. This lack of clastic metasedimentary rocks, coupled with its distinctive appearance in outcrop, and the fact that its mafic rocks are generally epidotic and chloritic, distinguishes it from rocks of underlying thrust sheets.

Waresville Amphibolite or Waresville Formation (abandoned)

Bentley and Neathery (1970, p. 26) used the name "Waresville Formation" for rocks here assigned to the Paulding Volcanic-Plutonic Complex stating that the unit had been named by Bentley in a report "in preparation" on Heard County, Georgia. The report has never been published, no type locality designation has been given (Waresville is a town in Heard County, Georgia), and no type section designated. The name Waresville Amphibolite has been used as a local name in Alabama by Neathery (1975) and Stow and Others (1984). Waresville Amphibolite or Waresville Formation are here abandoned as formal names.

Pumpkinvine Creek Formation (abandoned)

McConnell (1980) proposed the name Pumpkinvine Creek Formation for rocks assigned here to the Paulding Volcanic-Plutonic Complex in the Paulding thrust sheet, the Ropes Creek Metabasalt in the Ropes Creek thrust sheet, and the Powers Ferry Formation of the Sandy Springs Group in the Sandy Springs thrust sheet (his figure 3, 1980, p. 4). Because the rocks reside in three different thrust sheets (compare McConnell's figure 3 with figures 1 and 3 of this paper) we here abandon the name Pumpkinvine Creek Formation. McConnell's type locality for his Pumpkinvine Creek Formation is in Ropes Creek Metabasalt, and most of the rocks he called "Pumpkinvine Creek" are Ropes Creek Metabasalt.

Ropes Creek thrust sheet

The Ropes Creek thrust sheet is composed of the Ropes Creek Metabasalt, various unnamed, but mappable, volcanogenic alteration zones, iron formations, pelagic manganiferous metasedimentary rocks, the Canton Schist (a named alteration zone), and the Cedar Lake Member. Named units assigned to the Ropes Creek Metabasalt in Alabama include the Mitchell Dam, Beaverdam, and Ropes Creek amphibolites, most of the Ketchepedrakee amphibolite, part of the Doss Mountain amphibolite, the Slaughters Metagabbro, and the upper part of the Hillabee greenstone (Bentley and Neathery, 1970, Neathery, 1975; Tull and others, 1982; Stow, 1982; Neilson, 1983; Stow and others, 1984); these names are retained for informal local usage, but should be abandoned as formal names. In Georgia, we here abandon the New Georgia Group and Mud Creek Formation of Abrams and McConnell (1981) and the Univeter Formation of McConnell and Abrams (1984) including its Rose Creek Schist Member and Lost Mountain Amphibolite Member. We propose acceptance of the Cedar Lake Member, Villa Rica Gneiss, and Mulberry Rock Gneiss of Abrams and McConnell (1981; McConnell and Abrams, 1984), as modified here.

Ropes Creek Metabasalt (revised)

Bentley and Neathery (1970, p. 29-30) used the name Ropes Creek Amphibolite for exposures of amphibolite along Ropes Creek in northeastern Lee County, Alabama. This name has since been in common use in Alabama (Neathery, 1975; Sears and others, 1981; Stow and others, 1984). We here accept the type locality along Ropes Creek as proposed by Bentley and Neathery (1970), but propose that the name be changed to Ropes Creek Metabasalt.

The Ropes Creek Metabasalt is composed of ocher-weathering, massive to finely layered, locally laminated, locally pillowed (fig. 40), locally chloritic, commonly garnetiferous, locally magnetite-bearing, generally pyrite-bearing, green to greenish-black, hornblende-plagioclase and plagioclase-hornblende amphibolites with persistent but insignificant amounts (generally less than a very small fraction of a percent) of fine- to medium-grained, generally amphibole-bearing granofels. The final weathering product of the amphibolites is a very characteristic dark-red clayey soil. The mafic rocks of this unit are at least partially chloritized and (or) epidotized; few areas over a few square kilometers have escaped some chloritization, epidotization, or uralitization. Many of the rocks in the Ropes Creek Metabasalt contain disseminated pyrite, and locally, highly pyritiferous zones as much as 20 meters wide can be followed for as much as a hundred meters along strike.

One of the more distinctive features of the Ropes Creek Metabasalt is that it contains a diverse suite of iron-rich, siliceous, and manganiferous metavolcanogenic, largely exhalative, chemical metasediments, divided (terminology modified from Stanton, 1976b) into banded iron formations (Abrams and McConnell, 1982; McConnell and Abrams, 1983, 1984), ironstones, magnetite quartzites (Pate, 1980), manganiferous quartzites, and manganiferous schists. Some of the manganiferous rocks are similar to those found in the Zebulon and Atlanta thrust sheets, but in the Georgiabama thrust stack the iron-rich rocks are unique to the Ropes Creek thrust sheet and can be used almost like index fossils to identify it. Locally associated with the iron-rich rocks are thin layers of fibrous tourmaline (generally dravite). In addition, as far as we know (except for sulfide deposits in the Little River allochthon and Ducktown-type deposits), all of the massive volcanogenic sulfide deposits in Georgia and Alabama are within the Ropes Creek Metabasalt in the Ropes Creek thrust sheet and are closely associated with the iron formations (Pate, 1980; McConnell and Abrams, 1982) and tourmaline layers (also see Slack (1982) in mappable linear, siliceous and (or) aluminous, magnetite-, garnet-, and pyrite-rich alteration zones that were probably closely associated with submarine exhalative vents. Graphitic and manganiferous pelagic metasedimentary rocks are locally present.

Geochemical studies (Stow and others, 1984; Appendix B) indicate that the amphibolites in the Ropes Creek Metabasalt probably originated as seafloor basalts in an oceanridge type environment. Isotopic studies (Jones and others, 1973; Shaw and Wasserburg, 1984 - see section on West Point melange) also indicate that the Ropes Creek amphibolites are ancient oceanic crust. These interpretations are supported by the fact that the rocks in the Ropes Creek are almost entirely mafic (though ultramafic rocks and insignificant amounts of intermediate to felsic rocks also occur), contain volcanogenic sulfide-rich alteration zones and deposits (probably "black-smoker" deposits) with pelagic (commonly graphitic) sediments, and are associated with metavolcanogenic chemical sediments (iron-rich and, to a slightly lesser extent, manganese-rich cherts) and minor amounts of manganiferous pelagic sediments.

Mud Creek Formation (abandoned)

Abrams and McConnell (1981, p. 61) proposed the name Mud Creek Formation for "amphibolite, hornblende gneiss, biotite gneiss, mica schist and quartzite" exposed along Mud Creek north of Villa Rica, Georgia. The section along Mud Creek that

they designated the type section lies along the contact between the Zebulon Formation in the Zebulon thrust sheet and the Villa Rica Gneiss and Ropes Creek Metabasalt in the Ropes Creek thrust sheet. The Mud Creek Formation, as defined by Abrams and McConnell is not a mappable unit. Therefore, we here abandon the name Mud Creek Formation.

Cedar Lake Member (revised)

Abrams and McConnell (1981, p. 62-63) proposed the name Cedar Lake Quartzite Member of the Mud Creek Formation for a quartzite with layers and disseminated grains of magnetite and specular hematite that is exposed at Cedar Lake, in the Winston, Georgia 7 1/2' quadrangle. They also noted that the iron-phase of the quartzite grades locally into a manganiferous or garnetiferous quartzite. Abrams and McConnell (1981; McConnell and Abrams, 1984) mapped only the quartzites as the Cedar Lake Quartzite Member, and hence they show the unit as discontinuous in most places. Our mapping has also shown that the magnetite-hematite, magnetite, and manganiferous (spessartine) magnetite quartzites are discontinuous. However, these quartzose rocks are within a continuous, mappable unit of manganiferous schist (fig. 3). We here accept the name Cedar Lake and the type locality designated by Abrams and McConnell (1981), but modify Abrams and McConnell's (1981; McConnell and Abrams, 1984) Cedar Lake Quartzite Member of the Mud Creek Formation to the Cedar Lake Member of the Ropes Creek Metabasalt, and include the manganiferous rocks within it.

Villa Rica and Mulberry Rock Gneisses (revised)

The Ropes Creek thrust sheet also contains various K-feldspar-poor granitic rocks, including trondhjemites (Pate, 1980; Sanders, 1983), that are locally associated with gold-bearing quartz veins and alteration zones. Abrams and McConnell (1981) proposed the name Villa Rica Gneiss Member of the Mud Creek Formation for one such trondhjemite body in western Georgia and McConnell and Abrams (1984) proposed the name Mulberry Rock Gneiss Member of the Mud Creek Formation for another such body to the northwest (fig. 3). Pate (1980, p. 11-13) had already used the name Villa Rica Gneiss, stating: "While this unit has previously been termed a granite, petrographic examination reveals only minor amounts of potassium feldspar accompanied by relatively low percentages of ferromagnesian minerals..." We here accept the names Villa Rica Gneiss and Mulberry Rock Gneiss as proposed by Pate (1980) and Abrams and McConnell (1981; McConnell and Abrams, 1984). However, Abrams and McConnell (1981) and McConnell and Abrams (1984) assigned both gneisses to their Mud Creek Formation (abandoned) of their New Georgia Group (abandoned) and considered the Villa Rica Gneiss to be a metadacite; McConnell and Abrams (1984, p. 25) changed the name Villa Rica Gneiss Member of the Mud Creek Formation to "Villa Rica Gneiss (Metadacite) Member" of the Mud Creek Formation. The Villa Rica Gneiss is a plutonic rock, however, as recognized by Pate (1980) and Sanders (1983). It contains numerous xenoliths of Ropes Creek Metabasalt, including ultramafic rocks, it is of uniform plutonic texture, and it does not interfinger with its metavolcanic country rocks as indicated by Abrams and McConnell (1981) and McConnell and Abrams (1984); the Ropes Creek Metabasalt locally has very small amounts of intercalated felsic rocks with mineralogic compositions similar to the composition of the Villa Rica Gneiss, and there are dikes and sills of the gneiss in the country rocks near their contact with the gneiss; "metadacite" should be dropped from the name.

McConnell and Abrams (1984, p. 26) also applied the name Villa Rica Gneiss to another body of gneiss located roughly along strike from the Villa Rica Gneiss, stating:

"East-northeast of where the Villa Rica antiform plunges out, another gneiss very similar to the Villa Rica Gneiss is exposed in the crest of another elongate antiform. Sanders (personal commun., 1981) found that this gneiss is chemically dissimilar to the Villa Rica Gneiss and contains slightly higher concentrations of K_2O, MgO, total Fe, and CaO and slightly lower values for SiO_2 and Na_2O. Abrams and McConnell (1981a) and Abrams (1983) suggested that the two gneisses were equivalent based on their similar structural and stratigraphic position. In this report, we consider the chemical variations to be minor facies variations within a single lithostratigraphic unit and interpret this body to be equivalent to the Villa Rica Gneiss."

The body of gneiss in question, which we informally refer to as the Gothards Creek gneiss, bears little resemblance in outcrop or thin section to the Villa Rica Gneiss. It has a much better developed foliation, that is defined by biotite, whereas biotite is only a minor constituent of the Villa Rica Gneiss. The Gothards Creek gneiss has a different mineralogic composition and a distinctly different chemical composition from the Villa Rica Gneiss. Most important, the Gothards Creek gneiss and the Villa Rica Gneiss are in different thrust sheets; the Villa Rica is in the Ropes Creek thrust sheet, whereas the Gothards Creek is in the Zebulon thrust sheet. There is no scientific reason to correlate these two gneisses.

Univeter Formation (abandoned)

McConnell and Abrams (1984, p. 34-36) proposed the name Univeter Formation, defining it as follows:

"Centrally located in the New Georgia Group outcrop area is a sequence of amphibolite, hornblende gneiss, garnet-biotite-muscovite schist, banded iron formation, and garnet-chlorite schist termed the Univeter Formation (this report). The Univeter Formation was informally termed the Interstate formation by McConnell and Abrams (1982a, 1982b). This report serves to formally define the Univeter Formation for exposures at Univeter, southern Cherokee County. The Univeter Formation is traceable from Dallas on the southwest, through the Dahlonega area, to at least as far northeast as Nacoochee in White County (Ken Gillon, 1982). The Univeter Formation is composed of hornblende-andesine gneiss (amphibole/hornblende gneiss) with an intervening thin, garnet-biotite-muscovite schist $\pm$ amphibole. Also present locally is a thin (less than 5 ft.) banded iron formation and coarsely garnetiferous chlorite schist. The association of banded iron formation and chlorite schist with base and precious metal deposits in the Univeter Formation will be described in detail in a subsequent section. The hornblende-andesine gneiss in the Univeter Formation is interpreted to form two limbs of a fold. This unit is here termed the Lost Mountain Amphibolite Member of the Univeter Formation for exposures on Lost Mountain in western Cobb County. The intervening schist member is here termed the Rose Creek Schist Member for exposures near Rose Creek Church in southwestern Cherokee County. A typical characteristic of this member is the presence of biotite grains crossing the regional foliation in the rock (i.e., cross-biotite schist)."

The town of Univeter, Georgia (including the "type locality" marked by a small circle on McConnell and Abrams' figure 21), is underlain by the Zebulon Formation;

thin amphibolites present there along with schist are within the Zebulon. In fact, the section exposed in cuts behind buildings in Univeter are so characteristic of the Zebulon that they could be a reference section. The amphibolite at Lost Mountain is Ropes Creek Metabasalt in the Ropes Creek thrust sheet, and the garnetiferous schist unit that McConnell and Abrams (1984) called the "Rose Creek Schist Member" is part of a volcanogenic alteration zone and associated pelagic metasedimentary rocks within the Ropes Creek Metabasalt that Bayley (1928) named the Canton Schist. Because the "type locality" of McConnell and Abrams' (1984) Univeter Formation is in the Zebulon Formation in the Zebulon thrust sheet, whereas members of the formation are in the Ropes Creek thrust sheet, and for the reasons listed above, we here abandon Univeter Formation, Rose Creek Schist Member of the Univeter Formation, and Lost Mountain Amphibolite Member of the Univeter Formation.

Hillabee greenstone (informal)

The name Hillabee, whether modified by schist, chlorite schist, green schist, greenschist, or greenstone, has been in common use in Alabama since the latter part of the 19th century (Brewer, 1896; Prouty, 1923; Adams, 1926, 1933; Griffin, 1951; Carrington and Wigley, 1964; Clarke and Carrington, 1964; Neathery, 1972; Reynolds, 1972; Neathery and Reynolds, 1973; Tull and others, 1978; Tull, 1979; Tull and Stow, 1980a, 1980b, 1982; Stow and Tull, 1982; Tull, 1982; Stow, 1982) for the northern and northwesternmost infolded slices of the Ropes Creek, West Point melange, and Paulding thrust sheets (see Hillabee greenstone under Ropes Creek thrust sheet). Because its rocks reside in three separate thrust sheets, with very different origins, and probably slightly different ages, the name Hillabee should only be retained for informal usage.

APPENDIX B: GEOCHEMISTRY

The analyses presented in tables B-1--B-5 were all done in the laboratories of the U.S. Geological Survey, except for the Major-oxide analyses of rocks from the Corbin Gneiss which were done in the laboratory of the Georgia Geological Survey. Major-oxide analyses were done by the method described by Shapiro (1975), except for R and Ar samples in table B-5a which were done by X-ray spectroscopy. Rare-earth element analyses were done by instrumental neutron-activation. Trace element analyses for Ba, Cs, Th, U, Zr, Hf, Ta, Co, Cr, Sc, Zn, and Sb were done by instrumental neutron-activation, except where abundances of Ba, Zr, or Zn are low, in which case they were done by quantitative spectrographic analysis. Trace element analyses for Sr, Li, Ni, Cu, and Y were done by quantitative spectrographic analysis. Niobium content was determined spectrophotometrically using the method of Greenland and Campbell (1974). The analytical methods have been further described by Gottfried and others (1977) and Gottfried and others (1979).

For many years there has been a tendency, especially among Appalachian geologists, to assume that the geochemical characteristics of rocks have been altered to one degree or another by metamorphism, so that their present compositions may reflect neither their original compositions nor their original tectonomagmatic environments. The comprehensive study of amphibolites from the Alabama crystalline terrane by Stow and others (1984) has shown that for at least the Ropes Creek thrust sheet rocks there has been little alteration or migration of elements. Stow and others (1984, p. 422) stated:

> "There is general agreement that many constituents (that is, Y, Zr, Nb, Ti, Cr, REE) are relatively immobile during alteration and metamorphism, while others, especially alkali metals, may be highly mobile (Hanson, 1980; Pearce, 1975; Pearce and Cann, 1973; Smith and Smith, 1976). The degree to which element migration has occurred in amphibolites of the Alabama Piedmont cannot be quantitatively judged presently. Based on adherence to igneous trends, our data suggest that significant movement has not occurred, and, for the DMTA (Doss Mountain Amphibolite), they indicate that migration even for the alkali metals, is insignificant."

Bill Arp thrust sheet

Two sets of samples were analyzed from rocks of the Bill Arp thrust sheet in Georgia: (1) a set of 34 samples of Corbin Gneiss in the Allatoona Complex of Grenville basement rocks; and (2) a set of 28 samples of graphitic schists and phyllites from various units of the Great Smoky and Ellijay Groups.

Analyses of major-oxides, trace elements and rare earth elements in rocks from the Corbin Gneiss are given in table B-1. These analyses show that the Corbin is relatively rich in titanium, barium, zirconium, and light rare earth elements and relatively poor in calcium. All samples analyzed contain ilmenite and zircon in the norm. Three new analyses of "Fort Mountain Gneiss" given by McConnell and Costello (1984, p. 273) indicate that the Fort Mountain (= Corbin Gneiss) is also rich in titanium and has both ilmenite and rutile in the norm. Analyses given by Stieve (1984) from rocks of the Wacoochee Complex of Grenville basement in the Pine Mountain anticlinorium suggest that mafic and intermediate rocks there are also relatively rich in barium and titanium, and according to A.K. Sinha (unpublished data; oral commun., 1985) rocks of the Grenville basement in North Carolina are also relatively rich in titanium, barium, zirconium, and light rare earth elements. These geochemical features may be characteristic of Grenville basement metaigneous rocks in the southern Appalachians.

Table B-1a. Major oxide and normative mineral compositions, in weight percent, of rocks from the Corbin Gneiss in the Allatoona Complex of Grenville basement in northern Georgia. C samples analyst: Z.A. Hamlin, U.S.G.S.; others from Martin (1974), as modified by McConnell and Abrams (1984) - analyst: J.R. Landrum, Georgia Geological Survey.

Sample No.	68	C.1	64.A	94	49	99	81	C.2	112	62.B	97	95	92	88	28
Major-oxide composition															
SiO_2	57.84	61.1	62.24	63.20	63.46	63.54	65.20	65.6	66.16	66.20	66.40	67.20	67.20	67.80	67.80
Al_2O_3	17.40	17.0	15.50	14.20	14.50	16.70	14.30	16.4	16.00	14.80	15.00	13.50	14.80	12.80	15.00
Fe_2O_3	1.58	.58	1.65	1.00	1.15	1.98	2.73	1.0	.80	1.18	1.10	1.35	.78	.85	1.88
FeO	7.58	5.0	6.70	7.29	5.98	4.52	5.10	2.9	3.06	4.88	4.23	4.00	3.35	4.37	2.99
MgO	1.45	1.4	1.00	.98	.60	.54	1.95	.93	.80	.75	1.16	1.52	1.45	.98	.83
CaO	4.50	4.1	3.10	3.44	4.06	3.88	2.66	2.5	2.44	2.60	4.66	2.96	2.56	3.36	1.16
Na_2O	3.10	3.5	2.70	2.70	3.64	2.43	2.43	3.1	2.96	2.70	2.83	2.70	2.96	2.70	2.00
K_2O	2.77	3.8	3.97	4.34	3.00	3.73	2.65	5.3	6.26	4.22	3.61	4.22	5.06	4.58	4.82
H_2O+		.30						.30							
H_2O-	.34	.21	.25	.29	.13	.64	.62	.33	.30	.43	.43	.75	.44	.45	2.07
TiO_2	2.50	1.3	2.00	1.66	1.75	1.50	1.75	.82	.78	1.60	1.00	1.32	1.00	1.50	1.10
P_2O_5		.41						.31							
MnO	.09	.06	.08	.09	.05	.09	.08	.03	.02	.05	.04	.04	.02	.04	.04
CO_2		.04						.08							
Total	99.15	98.8	99.19	99.19	98.32	99.55	99.47	99.6	99.58	99.41	99.56	99.56	99.62	99.43	99.69
C.I.P.W normative mineral composition															
Q	13.266	13.062	19.464	18.056	19.021	23.773	30.214	19.809	16.792	24.982	23.109	25.274	21.174	25.162	32.822
C	1.008	.372	1.001			1.446	2.523	1.670	.937					4.261	
Z	.193	.133	.187	.191	.141	.175	.092	.113	.077	.134	.098	.078	.086	.099	.089
OR	16.369	22.456	23.461	25.647	17.729	22.043	15.660	31.321	36.994	24.983	21.333	24.938	29.902	27.066	28.484
AB	26.231	29.615	22.846	22.846	30.800	20.561	20.561	26.231	25.046	22.846	23.946	22.846	25.046	22.846	16.923
AN	22.640	18.447	15.699	13.817	14.374	19.707	13.406	10.633	11.892	13.251	17.572	12.261	12.161	9.287	6.095
DI				3.174	5.403				.598		4.917	2.329	.875	6.517	
HY	12.251	10.152	10.268	10.775	5.914	5.695	9.214	5.516	5.387	7.301	5.678	6.746	7.064	4.047	4.257
MT	2.291	.841	2.392	1.450	1.667	2.871	3.958	1.450	1.160	1.711	1.595	1.957	1.131	1.232	2.726
CM	.024	.006	.016	.026	.026	.009	.025	.004	.019	.008	.013	.012	.010	.022	.012
IL	4.748	2.469	3.798	3.153	3.324	2.849	3.324	1.557	1.481	3.039	1.899	2.507	1.899	2.849	2.089
AP		.950						.718							
CC		.091						.182							

Table B-1a continued.

Sample No.	76	110	C.3	79	78	51	108	25	53	19	82	30	C.4	40	104
Major-oxide composition															
SiO_2	68.00	68.02	68.3	68.36	68.40	68.60	68.64	68.90	69.00	69.12	69.60	70.14	70.3	70.60	70.80
Al_2O_3	14.80	15.80	14.5	16.00	15.30	14.80	15.00	15.80	13.80	15.00	14.20	15.30	14.7	14.30	14.7
Fe_2O_3	1.26	.97	.80	1.09	1.67	.47	2.01	1.46	1.76	1.13	1.16	.89	1.1	1.38	.92
FeO	2.92	2.55	2.4	1.90	2.55	2.55	1.97	2.11	2.92	2.04	2.92	2.26	2.3	1.82	1.60
MgO	1.00	.72	.52	.87	.58	.25	1.30	.77	.35	.40	.72	.68	.85	.20	.94
CaO	.76	1.74	1.8	.50	1.76	2.80	1.60	1.00	2.60	1.72	1.86	1.62	1.7	1.84	.10
Na_2O	2.70	2.83	3.0	2.00	2.43	2.96	2.00	2.70	2.63	2.56	2.17	3.37	2.6	2.70	1.62
K_2O	5.42	5.90	5.3	6.62	5.30	6.00	4.58	5.06	5.06	6.00	5.30	4.10	4.8	5.30	6.50
H_2O+			.66										.45		
H_2O-	1.30	.24	.10	1.54	.90	.45	1.59	1.10	.58	.88	.48	.56	.11	.83	1.80
TiO_2	1.50	.90	.51	.80	.80	.80	1.09	.78	1.00	.70	1.32	.80	.71	.78	.60
P_2O_5			.22										.30		
MnO	.04	.02	.03	.02	.02	.02	.02	.04	.04	.04	.02	.02	.04	.02	.00
CO_2			.88										.01		
Total	99.70	99.69	99.02	99.70	99.71	99.70	99.80	99.72	99.74	99.59	99.75	99.74	99.97	99.77	99.78
C.I.P.W normative mineral composition															
Q	27.378	22.866	27.407	28.279	21.525	33.842	29.704	27.470	26.001	30.451	29.245	29.748	31.542	29.748	34.340
C	2.979	1.445	2.974	2.264		3.715	3.936		1.023	1.402	2.269	.643	2.717	.643	4.709
Z	.071	.076	.076	.074	.048	.084	.060	.094	.066	.068	.063	.084	.078	.084	.076
OR	32.030	34.866	31.321	31.321	35.457	27.066	29.902	29.902	35.457	31.321	24.299	31.321	28.366	31.321	38.412
AB	22.846	23.949	25.384	20.561	25.046	16.923	22.846	22.254	21.661	18.361	28.515	22.846	22.000	22.846	13.708
AN	4.135	9.048	2.337	9.017	9.385	8.296	5.316	10.913	8.934	9.533	8.329	9.499	6.857	9.499	.799
DI					4.348			2.134							
HY	4.405	4.218	4.254	3.458	1.372	3.426	3.366	2.105	2.724	4.049	3.819	1.447	4.331	1.447	3.193
MT	1.827	1.406	1.160	2.421	.681	2.914	2.117	2.552	1.638	1.682	1.290	2.001	1.595	2.001	1.334
CM	.008	.016	.002	.010	.013	.010	.013	.015	.007	.011	.011	.007	.006	.007	.009
IL	2.849	1.709	.969	1.519	1.519	2.070	1.481	1.899	1.329	2.507	1.519	1.481	1.348	1.481	1.519
AP			.510										.695		
CC			2.001										.023		

Table B-1a continued.

Sample No.	58	67	113	34
SiO_2	71.60	71.80	73.26	73.60
Al_2O_3	12.50	13.80	13.50	13.00
Fe_2O_3	.99	.79	.68	1.09
FeO	2.62	2.62	1.82	1.09
MgO	.40	.30	.33	.24
CaO	3.04	2.10	2.08	2.04
Na_2O	2.70	2.00	2.00	2.63
K_2O	4.02	4.82	5.06	5.42
H_2O+				
H_2O-	.28	.85	.22	.40
TiO_2	.80	.60	.80	.30
P_2O_5				
MnO	.02	.02	.03	.01
CO_2				
Total	98.97	99.70	99.78	99.73

C.I.P.W. normative mineral composition

Q	33.512	35.077	36.485	32.983
C		1.291	.826	
Z	.076	.055	.042	.049
OR	23.756	28.484	29.902	32.030
AB	22.846	16.923	16.923	22.254
AN	10.122	10.923	10.668	7.666
DI	4.478			2.322
HY	1.410	3.945	2.332	.068
MT	1.435	1.145	.986	1.580
CM	.010	.012	.010	.005
IL	1.519	1.140	1.519	.570
AP				
CC				

Table B-1b. Trace element abundances, in parts per million, in rocks from the Corbin Gneiss. Analysts: P.A. Baedecker, N. Rain and E. Campbell.

Sample No.	68	C.1	64A	94	49	99	81	C.2	112	62.B	97	95	92	88	28
Rb	33	96	190	92	35	78	44	160	110	160	58	54	66	140	130
Ba	1330	3800	1410	1905	1895	1920	882	3000	2050	1525	1200	1690	2110	1325	1540
Sr	150	840	110	120	240	220	100	480	250	140	110	130	280	140	90
Cs	3.5	1.55	1.25	.6	.3	.6	.45	.5	.4	.4	1.3	.6	.4	.5	.4
Th	4.75	16.55	2.55	3.8	25.4	3.0	20.9	27.85	14.65	12.15	3.9	21.9	12.65	22.3	36.85
U	1.1	<1.3	2.3	1.85	1.0	1.1	3.1	1.3	1.0	1.5	1.4	1.4	.7	.8	2.6
Zr	961.5	660	929.5	948.5	700.5	869.5	457.5	560	382	668.5	490	390	429.5	490.5	444.5
Hf	20.6	16.25	21.7	23.1	16.95	21.7	11.55	13.2	8.6	15.55	12.5	13.8	10.2	11.65	11.85
Nb	40	27	50	46	26	38	28	22	19	29	30	26	20	21	19
Ta	3.09	1.51	6.7	5.66	3.25	5.38	2.39	.68	6.63	2.37	6.00	6.49	4.84	3.03	2.70
Co	13.25	11.2	19.35	26.85	16.7	15.05	19.1	6.9	21.15	9.15	18.9	24.3	18.4	14.6	10.95
Li	42		52	35	23	27	62		44	38	60	40	28	32	22
Ni	5	8	4	17	16	4	20	5	3	4	<4	<4	4	15	9
Cr	112	28.85	73.75	121	122.5	43.2	118	18.95	87.45	36.7	59.5	57.7	46.75	100.5	56.9
Sc	22.6	15.82	20.05	23	14	18.3	17.25	8.52	6.36	16.55	12.40	11.40	8.79	8.57	12.45
Cu	32	22	30	40	29	13	40	17	14	23	19	25	8	37	24
Zn	176.5	150	200	341	122.5	144.5	115	86	75.5	132.5	125	117	100.5	96	156.5
Sb	.5	1.85	.4	<.9	<.7	.5	<.8	1.75	.35	<.7	<.7	<.9	.4	<.7	<.7
Y	120	44	130	120	50	87	100	35	110	58	55	28	41	110	

Table B-1b continued.

Sample No.	76	110	C.3	79	78	51	108	25	53	19	82	30	C.4	40	104
Rb	170	92	220	69	180	78	94	130	86	94	64	260	140	90	58
Ba	1655	1850	1600	1370	1240	2295	1330	1580	2295	1745	1340	1295	1600	1685	1400
Sr	94	130	260	84	110	130	280	110	150	150	110	94	380	94	60
Cs	.4	.4	1.9	.4	.7	.3	.3	.35	.4	.35	.5	.6	.75	.5	.7
Th	20.5	23.45	17.85	18.1	21.85	35.85	27.85	17.7	17.6	18.55	21.75	27.9	28.8	25.25	25.3
U	1.4	1.4	2.55	1.3	2.25	1.4	1.4	1.65	.7	1.15	1.85	3.2	1.7	1.2	1.9
Zr	351	378.5	380	256	366.5	237.5	419.5	300	469	327	340.5	315.5	390	418.5	378
Hf	8.95	9.15	12.15	6.3	9.0	6.95	10.0	7.75	10.9	8.4	8.3	9.65	8.4	10.2	10.1
Nb	22	14	20	18	22	12	17	14	17	16	22	22	17	17	25
Ta	6.11	1.91	.99	6.79	6.76	1.54	.92	2.7	1.6	1.68	7.69	4.29	.64	2.76	8.36
Co	22.9	8.6	3.45	23.8	25.9	7.95	4.65	9.6	10.65	7.25	27.9	11.25	3.9	12.05	26.0
Li	56	48		27	31	42	46	23	32	22	49	52		28	96
Ni	5	9	3	<4	4	8	4	6	11	5	4	5	5	6	<4
Cr	35.9	74.15	9.1	41.1	48.15	59.75	48.5	58.25	71.75	32.75	51.75	50.85	25.9	31.35	42.0
Sc	8.16	5.67	6.89	6.35	8.31	6.04	8.47	7	9.01	7.13	7.93	5.79	7.33	5.98	6.64
Cu	16	12	24	9	20	12	8	18	22	8	13	15	6	8	14
Zn	92.5	69.5	77	118	58	51	64.5	50	94.5	44	55.5	85	56	59	66
Sb	<.6	.3	3.85	<.6	.3	.3	<.6	.2	.4	<.6	<.6	.3	1.6	<.5	<.6
Y	35	57	47	21	63	33	61	56	41	75	39	280	63	33	35

Table B-1b continued.

Sample No.	58	67	113	34
Rb	180	62	48	66
Ba	1225	2305	1570	1565
Sr	100	130	100	100
Cs	.45	.45	.4	.25
Th	19.55	.75	17.2	14.8
U	2.15	<.8	1.2	.7
Zr	377.5	273.5	210	244.5
Hf	9.15	6.9	6.0	5.7
Nb	17	11	9.6	9.6
Ta	3.67	2.30	1.36	2.27
Co	12.35	9.3	5.5	9.75
Li	30	66	24	14
Ni	4	<4	4	4
Cr	46.6	54.0	47.4	25.5
Sc	6.21	7.15	3.97	3.95
Cu	24	16	8	7
Zn	60	57	40	41
Sb	<.5	<.5	<.4	<.4
Y	33	19	22	18

Table B-1c. Rare earth elements abundances, in parts per million, in rocks from the Corbin Gneiss. Analyst: P.A. Baedecker.

Sample No.	68	C.1	64.A	94	49	99	81	C.2	112	62.8	97	95	92	88	28
La	105.5	154	99	103.5	170.5	96.5	93	125.5	87.5	94	102	118	92.5	99	136.5
Ce	218	268.5	212.5	198.5	312	188.5	175.5	229	160.5	190	188	223	173	194.5	267
Nd	130	128	143.5	103	132.5	102	79	104	72	102.5	101	103	71.5	88	110
Sm	25.15	20.2	29.3	22.8	20.95	22.0	18.3	16.9	14.4	20.45	18.9	18.1	12.65	16.0	22.3
Eu	4.01	3.89	3.29	3.47	3.23	412.5	2.23	2.83	2.31	2.75	2.64	2.66	2.67	2.11	2.77
Gd	18.05	13.8	19.45	16.5	13.45	15.6	14.2	9.0	9.4	15.35	10.6	11.4	8.4	10.7	16.3
Tb	3.00	1.81	3.52	2.77	1.81	2.37	2.32	1.36	1.33	2.31	1.88	1.79	.93	1.35	2.47
Ho	2.7	1.0	2.8	2.45	1.1	1.7	1.9	.6	1.2	1.75	1.8	.7	.65	.7	1.6
Tm	1.04	.95	.89	.85	.44	.89	.96	<.89	<.2	.70	<.2	.44	<.2	<.2	.84
Yb	7.05	2.8	5.7	6.85	2.3	6.05	7.0	1.6	2.95	5.05	2.9	3.5	1.65	1.8	4.35
Lu	.97	.39	.79	1.05	.31	.87	1.01	.23	.38	.70	.39	.50	.23	.27	.58

Sample No.	76	110	C.3	79	78	51	108	25	53	19	82	30	C.4	40	104
La	101	97	109	63	87	129	103	82.5	90.5	88	94.5	129	101.5	101.5	105
Ce	168.5	184	200.5	124	149.5	253.5	205.5	156.5	172	160.5	153	179.5	186	200	164
Nd	69	80.5	91.5	51	62	108.5	83.5	64.5	74	84.5	69.5	127.5	88.5	77.5	79
Sm	15.5	14.45	18.0	10.6	14.95	18.25	16.85	14.45	13.25	15.55	13.8	27.75	16.8	16.1	19.3
Eu	2.19	2.13	2.33	1.47	1.63	2.47	2.15	2.04	2.56	2.29	1.86	3.41	1.97	2.12	2.36
Gd	10.3	10.7	10.5	6.2	10.05	12.05	11.9	11.05	9.4	11.85	9.35	24.55	11.9	10.35	12.4
Tb	1.51	1.52	1.65	.92	1.59	1.31	1.79	1.72	1.28	1.77	1.45	4.22	1.83	1.6	1.63
Ho	.95	1.15	.9	.4	1.4	.85	1.4	1.05	.75	1.5	.9	3.7	1.3	1.0	1.5
Tm	<.2	.72	<.84	<.2	<.2	.44	.69	.66	.42	.94	<.2	2.26	.57	.58	<.2
Yb	2.4	4.4	1.6	2.1	3.75	2.5	5.75	3.55	2.05	6.4	3.0	13.8	3.9	4.1	3.6
Lu	.33	.59	.22	.30	.60	.38	.78	.43	.27	.87	.44	1.83	.51	.58	.47

Sample No.	58	67	113	34
La	84.5	34	73	73.5
Ce	155	52.5	140	136.5
Nd	68.5	28	46	49
Sm	14.35	4.6	10.3	11.35
Eu	1.62	3.34	1.87	1.84
Gd	9.7	3.15	6.2	7.1
Tb	1.08	.48	.91	.87
Ho	.8	.5	.4	.9
Tm	.38	.24	.38	.37
Yb	2.55	1.7	2.4	2.65
Lu	.35	.24	.33	.39

Major oxide analyses of graphitic schists and phyllites from various units in the Ocoee Supergroup and Ellijay Group are given in table B-2. Like the Corbin Gneiss, these metasedimentary rocks are relatively rich in barium, titanium, zirconium, and light rare earth elements and anomalously poor in calcium. All samples analyzed contain ilmenite and zircon in the norm and many contain rutile as well. Comparison of the data from the Corbin Gneiss and various Ocoee Supergroup and Ellijay Group rocks (including rocks as high in the sequence as the Nantahala Formation of the Ellijay Group) indicates a striking similarity that we interpret as indicating that these transported sequences were all derived from Grenville basement that was, or was very much like, the Allatoona Complex. The anomously low CaO content of the pelitic rocks strongly suggests rapid deposition from basement that was relatively poor in CaO, with probably no contribution from carbonate rock-bearing cratonic sequences.

Paulding thrust sheet

A set of 13 samples of representative rock types from the Paulding Volcanic-Plutonic Complex were analyzed; the data are presented in table B-3. In the analyzed samples silica ranges from 52.8 percent to 63.5 percent (table B-3a) corresponding to a range of basalt to dacite, with most samples falling into the andesite range. The assemblage of mafic to intermediate igneous rocks in the Paulding Complex appears to be calc-alkalic to calcic (Peacock, 1931), with an alkali-lime index between 57 and 63 - the scatter may be due to alteration, but the limited number of analyses is insufficient to define such alteration. The assemblage plots toward the alkaline side on an F'-M-A diagram (fig. 65), and within the calc-alkaline field of Irvine and Barager (1971). Thus, major element analyses support field and petrographic data indicating that the Paulding Volcanic-Plutonic Complex is an island arc assemblage.

Trace element abundances in rocks from the Paulding Complex are given in table B-3b. The Paulding rocks appear to be enriched in Ba and Sr and somewhat depleted in Cu, Co, Cr, and Ti (low in TiO_2 - table B-3a). Y-Nb ratios average 2.77 and range from 1.22 to 3.39; these low ratios are compatible with island arc derivation for the rocks.

Chondrite-normalized rare-earth element (REE) patterns for rocks from the Paulding Complex (fig. 66) show consistent light rare-earth (LREE) element enrichment and trends compatible with arc environments. Discrimination diagrams (fig. 67), widely used to determine original tectonomagmatic environment, also support the interpretation of an arc environment for derivation of the Paulding Complex rocks. On a Ti-Zr diagram (fig. 67a) the Paulding rocks fall mostly in the field of calc-alkalic basalt of island arc series, with one sample falling in the field of low-potassium tholeiitic basalt of island arc series. On a TiO_2-Zr diagram (fig. 67b) the Paulding rocks plot entirely within the arc field, and on an Hf-Ta-Th diagram (fig. 67c) they plot mostly within the arc field (field of basalts from destructive plate margins) and within the calc-alkaline part of that field, with one sample falling in the field of enriched-type mid-ocean-ridge basalts and tholeiitic within-plate basalts. On an Al_2O_3/TiO_2-TiO_2 diagram (fig. 68a) some Paulding samples plot in the arc field whereas others plot between the arc field and the field that includes mid-ocean-ridge basalts; "Hillabee" dacites are also plotted. On a CaO/TiO_2-TiO_2 diagram (fig. 68b) two of the Paulding samples plot in a field for primitive "source relatively undepleted" arc field and the others plot between that arc field and the field that includes mid-ocean-ridge basalts; "Hillabee" dacites are also plotted. It must be again emphasized that most of these Paulding rocks are not basalts, so use of these discrimination diagrams is not

Table B-2a. Major oxide compositions of graphitic schists and phyllites from the Ocoee Supergroup and Elijay Group in the Bill Arp thrust sheet in Georgia. Analyst: Nancy Skinner.

Sample No.	GP.2	GP.3	GP.4	GP.5	GP.8	GP.9	GP.10	GP.11	GP.12	GP.13	GP.14	GP.15	GP.16	GP.17	GP.18
Major-oxide composition															
SiO_2	42.5	47.9	49.9	50.9	51.7	55.8	56.4	57.0	57.2	57.7	59.2	59.6	59.7	59.8	61.0
Al_2O_3	29.7	29.2	28.6	24.9	24.6	20.5	19.2	20.7	21.9	19.1	21.1	19.9	21.4	19.7	18.4
Fe_2O_3	6.8	4.9	4.7	1.7	4.7	1.6	5.4	5.2	5.2	2.6	5.5	6.3	3.8	6.4	3.7
FeO	1.2	.48	.55	4.9	7.2	6.2	1.2	.50	.80	1.8	.08	.20	.48	.16	1.4
MgO	1.3	.72	.76	1.4	1.0	2.4	2.1	1.3	.62	1.5	.54	1.4	1.1	.85	1.4
CaO	.00	.00	.01	.22	.04	1.5	.46	1.2	.00	.61	.00	.00	.00	.00	.47
Na_2O	.28	1.3	1.0	.70	.46	2.3	1.7	.40	.42	2.0	.76	.21	.43	.43	.29
K_2O	7.6	6.9	6.1	6.2	7.0	3.5	3.3	5.4	4.5	3.9	5.5	6.4	5.1	5.6	5.4
H_2O+	5.6	4.4	3.6	3.4	3.1	2.9	3.2	3.7	4.7	2.8	3.2	2.6	3.9	3.3	1.9
H_2O-	.91	.30	.21	.17	.32	.00	.30	.71	.82	1.1	.22	.21	.44	.61	.31
TiO_2	1.2	.93	1.7	1.2	1.2	.79	.80	1.0	1.2	.70	1.2	.77	1.1	1.1	.91
P_2O_5	.20	.09	.08	.17	.25	.28	.29	.34	.27	.15	.10	.11	.24	.31	.13
MnO	.08	.10	.05	.08	.03	.10	.06	.04	.04	.33	.01	.02	.02	.02	.05
CO_2	.02	.01	.01	.02	.02	.63	.02	.01	.02	.01	.01	.01	.01	.01	.01
IL less $CO_2 + H_2O$	1.1	1.6	2.0	3.0	4.2	.49	4.2	1.5	1.7	5.1	1.2	1.7	1.5	1.9	3.8
Total	98.49	98.83	99.27	99.01	99.34	98.99	98.63	99.30	99.39	99.40	98.68	99.43	99.22	100.19	99.17
C.I.P.W. normative composition															
Q	11.57	13.164	19.824	18.320	18.626	20.589	30.551	30.339	38.732	27.638	33.626	32.272	37.804	36.766	35.788
C	21.390	19.687	20.427	16.996	16.637	12.271	12.683	12.755	16.947	10.768	14.101	12.767	15.682	13.549	11.442
Z	.024	.052	.117	.056	.181	.034	.072	.082	.084	.054	.048	.042	.098	.042	.060
OR	44.913	40.776	36.048	36.639	41.367	20.683	19.502	31.912	26.593	23.047	32.503	37.821	30.139	33.094	31.912
AB	.442	10.528	8.084	5.923	1.993	19.461	14.385	3.385	.427	16.923	5.386	1.065	1.025	.466	2.454
AN				.119		1.798	.409	3.939		2.243					1.739
NC	.389	.095	.076		.384				.632		.211	.144	.528	.641	
NY	3.237	1.793	1.893	9.244	9.874	14.917	5.230	3.237	1.544	4.349	1.345	3.486	2.739	2.117	3.486
MT	.637			2.465	6.815	2.320	1.741			3.770					2.033
CM	.020	.016	.024	.019	.018	.019	.011	.012	.017	.016	.024	.013	.016	.014	.016
HM	6.361	4.900	4.700				4.200	5.200	5.200		5.500	6.300	3.800	6.400	2.298
IL	2.279	1.217	1.253	2.279	2.279	1.500	1.519	1.134	1.765	1.329	.174	.456	1.048	.371	1.728
RU		.289	1.041					.403	.271		1.108	.530	.548	.904	
AP*	.463	.209	.185	.394	.579	.649	.672	.788	.626	.348	.232	.255	.556	.718	.301
CC				.045		1.433	.045	.023		.023					.023

* Most analyses contain insufficient ca to form the proper amount of apatite.

Table B-2a continued.

Sample No.	GP.19	GP.20	GP.21	GP.22	GP.23	GP.24	GP.25	GP.26	GP.27	GP.28	GP.29	GP.30	GP.31
SiO_2	61.3	61.5	62.1	62.2	62.5	62.7	63.7	64.2	64.3	65.6	66.0	67.7	71.3
Al_2O_3	19.0	20.4	21.4	20.4	20.4	18.5	20.2	19.8	19.4	18.7	17.1	17.5	15.1
Fe_2O_3	2.3	4.5	2.3	4.9	2.4	3.1	3.5	4.3	3.4	2.2	1.9	2.1	2.6
FeO	3.2	.17	.84	.42	.20	1.6	.26	.08	.24	.44	.16	.66	.64
MgO	1.7	.43	.74	.30	1.4	1.3	.54	.80	1.1	.46	.91	1.8	.44
CaO	1.6	.00	.00	.00	.00	.48	.00	.00	.00	.00	.26	.50	.00
Na_2O	2.9	.95	1.2	.44	.23	1.5	1.0	.53	.14	.08	.29	.18	.06
K_2O	3.3	4.2	4.5	3.7	6.7	4.4	3.9	5.5	5.5	8.0	4.0	6.9	5.2
H_2O+	1.3	3.2	2.5	4.2	2.3	2.2	3.2	2.9	3.2	1.6	3.2	2.0	1.9
H_2O-	.27	.35	.23	.92	.04	.66	.41	.23	.28	.22	1.4	.08	.18
TiO_2	.94	1.0	1.1	.87	.72	.98	1.0	.63	1.0	1.0	1.5	.85	.73
P_2O_5	.28	.13	.12	.09	.09	.18	.15	.10	.11	.10	1.3	.14	.09
MnO	.10	.05	.07	.06	.00	.08	.04	.05	.02	.03	.02	.00	.02
CO_2	.01	.03	.02	.01	.02	.00	.01	.02	.00	.01	.01	.01	.01
IL less $CO_2 + H_2O$	1.9	3.8	1.6	2.7	2.2	.57	2.4	1.8	1.5	1.4	1.3		.38
Total	100.05	100.08	99.80	99.61	99.32	99.08	99.40	99.48	99.41	100.54	99.35	100.42	98.65

C.I.P.W. normative composition

Q	35.254	28.947	39.118	41.169	32.607	41.910	40.315	36.948	39.104	34.093	56.776	36.842	51.029
C	11.171	11.384	15.221	14.588	12.542	12.825	13.825	12.435	12.754	10.000	14.890	9.139	9.559
Z	.068	.078	.080	.088	.044	.133	.098	.040	.157	.159	.157	.044	.060
OR	19.502	24.820	26.593	21.865	39.594	26.002	23.047	32.503	32.503	47.276	23.638	40.776	30.730
AB	10.154	22.999	6.734	9.301	3.125	1.946	11.006	7.268	3.571	.219		1.523	
AN	6.233					1.460						1.631	
NC		.311	.264	.172	.121		.325	.241	.185	.195	2.699		.193
HY	6.841	1.071	1.843	.747	3.486	3.237	1.345	1.992	2.739	1.146	2.266	4.483	1.096
MT	3.335					2.562							.002
CM	.012	.013	.014	.018	.014	.015	.013	.009	.014	.013	.012	.017	.010
HM		4.500	2.300	4.900	2.400	1.333	3.500	4.300	3.400	2.200	1.900	2.100	2.598
IL	1.785	.459	1.915	1.006	.413	1.861	.626	.398	.540	.986	.373	1.383	1.386
RU		.759	.092	.340	.503		.670	.420	.716	.481	1.304	.122	
AP*	.649	.301	.278	.209	.209	.417	.348	.232	.255	.232	3.012	.324	.209
CC	.023											.023	

* Most analyses contain insufficient ca to form the proper amount of apatite.

Table B-2b. Trace element abundances, in parts per million, in graphitic schists and phyllites from the Ocoee Supergroup and Ellijay Group in the Bill Arp thrust sheet. Analysts: J.D. Fletcher.

Sample No.	GP.2	GP.3	GP.4	GP.5	GP.8	GP.9	GP.10	GP.11	GP.12	GP.13	GP.14	GP.15	GP.16	GP.17	GP.18
Rb	221	246	212	183	200	119	120	171	150	138	201	230	164	175	149
Ba	1833	1411	1093	923	2381	322	501	1106	962	1015	653	1961	1012	1271	1292
Sr	120	360	360	240	220	320	140	140	110	170	92	20	120	110	180
Cs	2.4	3.9	4.2	4.6	2.3	4.4	3.0	2.6	3.6	2.1	4.3	1.1	2.0	1.3	2.5
Th	25.7	28.0	22.7	18.6	20.4	11.0	27.15	20.4	24.7	15.3	15.2	16.6	27.9	26.7	11.1
U	5.7	2.8	3.0	3.8	4.1	3.6	3.5	3.6	5.3	4.3	4.9	2.3	4.3	5.6	2.7
Zr	210	260	580	280	900	170	360	410	420	270	240	210	490	290	300
Hf	7.1	6.9	14.9	8.4	18.3	5.7	10.95	9.9	11.1	6.1	5.8	6.5	11.9	9.7	7.4
Nb	22	19	30	26	31	28	<10	22	38	18	17	18	20	23	<10
Ta	2.06	1.50	2.58	1.70	2.13	1.23	1.24	1.14	2.53	1.00	1.70	1.00	1.28	1.30	1.06
Co	6.4	3.6	1.3	36.9	1.7	16.8	10.2	1.2	8.4	38.2	2.3	.2	2.7	.2	16.5
Ni	17	<2	<2	36	<2	30	19	3	6	34	<2	<2	7	<2	30
Cr	91	75	110	88	85	89	52	56	80	76	110	62	73	64	84
Sc	27.05	26.81	22.53	22.58	23.95	13.12	15.55	19.71	14.50	18.46	21.16	16.98	20.85	15.79	18.45
Cu	40	72	30	58	29	51	46	34	33	100	45	34	45	55	43
Zn	126	104	191	72	87	95	123	64	119	73	40	32	99	37	114
Sb	<1.4	<1.6	<1.3	<1.5	<1.4	.8	.8	1.3	<1.0	<1.2	<1.4	.7	.7	2.3	.6
Y	70	15	<10	68	87	81	76	54	34	49	59	59	75	42	56

Table B-2b continued.

Sample No.	GP.19	GP.20	GP.21	GP.22	GP.23	GP.24	GP.25	GP.26	GP.27	GP.28	GP.29	GP.30	GP.31
Rb	162	136	203	114	244	183	154	197	217	173	153	160	110
Ba	542	844	887	846	1895	907	783	611	1066	873	751	588	668
Sr	240	160	120	84	40	220	100	70	54	84	70	28	30
Cs	7.2	2.0	3.5	2.4	1.4	4.6	3.2	1.8	2.1	1.6	2.1	3.0	1.7
Th	23.1	22.0	25.4	22.7	24.2	22.3	22.4	25.3	21.8	16.6	41.3	14.3	12.0
U	5.3	5.3	4.8	5.4	2.3	5.1	4.3	2.9	3.5	4.6	6.2	4.6	3.3
Zr	340	390	400	440	220	660	490	200	780	790	780	220	300
Hf	10.0	11.1	11.3	11.1	5.3	15.9	12.0	7.2	18.2	16.6	15.5	5.9	7.0
Nb	22	31	28	27	15	24	25	<10	30	26	39	22	21
Ta	2.31	2.27	2.40	2.41	1.17	2.27	2.06	0.92	2.47	1.67	1.64	1.30	1.16
Co	9.5	5.9	0.6	12.9	0.4	4.4	4.2	0.5	1.2	9.9	.2	2.0	1.2
Ni	18	5	<2	9	<2	<2	<2	<2	<2	8	<2	<2	<2
Cr	54	60	64	82	66	69	59	40	65	62	54	78	45
Sc	10.37	13.41	13.90	12.39	18.27	13.93	12.88	16.68	13.07	12.85	18.88	15.35	14.95
Cu	20	24	8	34	5	18	27	31	22	9	57	11	28
Zn	111	45	68	67	46	71	52	31	37	25	42	26	<25
Sb	<1.1	<1.3	.6	<.9	<1.2	<1.3	<1.2	1.0	<.8	<1.1	2.2	.6	.6
Y	25	<10	14	18	64	47	<10	36	36	58	76	26	52

Table B-2c. Rare earth element abundances, in parts per million, in graphitic schists and phyllites from the Ocoee Supergroup and Ellijay Group in north Georgia. Analyst: L.J. Schwarz.

Sample No.	GP.2	GP.3	GP.4	GP.5	GP.8	GP.9	GP.10	GP.11	GP.12	GP.13	GP.14	GP.15	GP.16	GP.17	GP.18
La	73	14	9	80	308	40	43.5	98	59	68	85	71	90	96	65
Ce	130	77	20	148	252	84	100.5	182	100	143	120	150	184	192	136
Nd	82	13	<26	71	275	35	54	93	49	68	90	68	87	85	68
Sm	18.4	2.8	1.5	13.9	53.6	8.2	11.3	18.1	10.9	14.6	19.0	13.2	17.5	18.3	12.8
Eu	2.86	.52	.40	2.28	7.56	1.33	1.31	2.87	1.46	2.11	2.24	1.81	2.31	2.36	2.49
Gd	10.4	1.8	3.8	9.5	26.7	5.3	8.0	11.1	7.0	8.6	11.2	8.0	10.7	12.0	9.3
Tb	2.32	.51	<1.1	1.80	4.37	1.05	1.34	1.83	1.30	1.61	1.87	1.53	2.00	1.89	1.44
Ho	2.5	<.8	<.7	1.4	2.8	1.2	1.4	1.1	1.5	1.4	1.8	1.3	2.0	1.5	1.2
Tm	1.20	.23	.45	.78	1.14	.62	.70	.62	.71	.73	.79	.63	.89	.66	.61
Yb	8.3	2.0	2.1	6.0	6.6	3.5	5.3	5.2	5.1	5.1	5.3	4.7	7.2	4.1	4.1
Lu	1.15	.27	.34	.81	.89	.47	.70	.73	.70	.68	.69	.61	.90	.56	.58

Sample No.	GP.19	GP.20	GP.21	GP.22	GP.23	GP.24	GP.25	GP.26	GP.27	GP.28	GP.29	GP.30	GP.31
La	40	69	55	69	110	59	37	50	34	54	161	57	50
Ce	76	125	95	112	211	113	64	113	64	119	301	122	107
Nd	40	50	46	57	104	47	30	47	32	48	134	49	54
Sm	9.0	10.4	8.9	9.8	21.6	11.4	5.3	9.0	6.8	11.3	24.7	10.3	11.3
Eu	1.41	1.55	1.21	1.44	2.66	1.62	.84	1.23	1.01	1.90	3.14	1.51	1.77
Gd	5.8	5.6	5.2	6.0	12.6	8.3	4.0	6.4	5.9	7.9	15.7	5.1	8.5
Tb	1.21	.90	.76	.99	2.11	1.31	.48	1.13	1.00	1.47	2.73	1.04	1.26
Ho	1.3	.6	.8	1.0	1.9	1.5	.5	1.5	1.2	1.3	2.3	1.4	1.4
Tm	.55	.25	.46	.39	.76	.66	.20	.64	.74	.96	.79	.70	.60
Yb	3.9	1.4	2.9	2.6	4.8	5.0	2.2	4.5	4.8	6.2	5.8	4.1	4.2
Lu	.56	.18	.46	.39	.72	.74	.33	.60	.71	.94	.79	.59	.61

Table B-3a. Major oxide and normative compositions, in weight percent, of rocks from the Paulding Volcanic-Plutonic Complex in the Paulding thrust sheet. Analysts: E. Campbell, M. Doughten, J. Gillison, J. Reid, and H. Smith.

Sample No.	B.7J	B.7K	B.7H	B.7I	B.7L	B.7C	B.7G	B.7A	B.7B	B.7E	B.7D	B.7F	WG.33
Major-oxide composition													
SiO_2	52.8	53.9	56.5	57.3	57.2	57.4	57.6	57.9	61.5	61.6	61.7	62.4	63.5
Al_2O_3	18.5	18.3	17.7	17.3	16.0	16.7	16.9	17.0	17.4	17.0	17.8	16.0	15.4
Fe_2O_3	4.9	4.3	3.9	4.2	3.6	2.9	2.5	3.9	2.7	3.1	2.0	3.4	2.1
FeO	2.5	3.2	3.3	3.8	4.2	4.5	3.8	3.7	2.2	2.1	2.2	2.8	3.1
MgO	2.8	2.9	2.9	2.7	3.4	4.2	3.1	2.5	1.5	1.6	1.5	2.4	2.9
CaO	9.2	8.2	8.0	7.8	5.2	6.8	5.6	7.3	5.3	5.3	5.1	7.0	6.3
Na_2O	4.5	4.9	5.2	4.4	5.3	4.6	5.2	4.1	6.1	5.9	6.0	4.3	3.2
K_2O	1.0	1.1	0.82	1.0	2.0	0.23	2.3	1.2	.92	.79	.49	.78	1.1
H_2O+	1.6	1.6	1.0	1.1	1.2	1.1	1.1	1.2	.60	.72	.58	.85	.35
H_2O-	.89	.80	.53	.37	.41	.39	.35	.39	.24	.23	.28	.19	.19
TiO_2	.57	.59	.57	.63	.54	.53	.55	.66	.52	.56	.52	.37	.35
P_2O_5	.19	.19	.21	.20	.04	.14	.20	.18	.16	.18	.18	.11	.12
MnO	.21	.14	.16	.19	.14	.14	.15	.18	.10	.11	.06	.16	.08
CO_2	.05	.07	.07	.07	.04	.04	.06	.05	.05	.04	.06	.06	.08
Total	99.71	100.19	100.86	100.06	99.27	99.67	99.41	100.26	99.29	99.23	99.27	100.82	98.77
CIPW normative composition													
Q	3.173	2.352	4.728	9.270	3.507	8.822	2.849	11.626	10.566	12.415	12.716	17.850	22.956
Z	.024	.018	.026	.026	.013	.018	.020	.020	.034	.019	.032	.011	.017
OR	5.910	6.501	4.846	5.910	11.819	1.359	13.592	7.091	5.437	4.669	2.896	4.609	6.501
AB	38.077	41.461	44.000	37.231	44.846	38.923	44.000	34.692	51.615	49.923	50.769	36.384	27.077
AN	27.336	24.700	22.543	24.510	13.970	24.249	15.989	24.448	17.389	17.579	20.200	22.061	24.416
DI	13.097	11.432	12.291	10.086	8.372	6.784	8.345	8.435	6.125	5.835	2.917	9.370	4.638
HY	.901	3.400	3.538	4.683	8.518	12.422	7.941	4.969	1.943	1.808	3.324	3.501	8.506
MT	7.081	6.235	5.655	6.090	5.220	4.205	3.625	5.655	3.915	4.495	4.060	4.930	3.045
CM	.012	.010	.008	.003	.009	.010	.013	.002	.003	.003	.004	.010	.009
HM	.016												
IL	1.083	1.121	1.083	1.197	1.026	1.007	1.045	1.254	.988	1.064	.988	.703	.665
AP	.440	.440	.487	.463	.463	.324	.463	.417	.371	.417	.417	.255	.278
CC	.114	.159	.159	.159	.091	.091	.136	.114	.114	.091	.136	.136	.182

Table B-3b. Trace element abundances, in parts per million, in rocks from the Paulding Volcanic-Plutonic Complex. Analysts: R. Johnson, N.J. Rose, B. McCall, G. Sellers, J. Lindsay.

Sample No.	B.7J	B.7K	B.7H	B.7I	B.7L	B.7C	B.7G	B.7A	B.7B	B.7E	B.7D	B.7F	WG.33
Rb	44	47	21	13	54	30	88	41	15	11	15	17	55
Ba	381	426	190	390.5	394	293	375	556	209	160	200	160	389
Sr	455	400	342	182	210	249	294	183	230	224	225	282	330
Cs	.3	.5	.4	.3	.5	.4	.7	.5	.2		.4	.3	.6
Th	4.5	4.2	4.5	5.1	4.1	5.6	4.5	5.1	6.0	6.0	5.9	3.7	7.9
U	6.2	2.3	2.0	2.3	1.7	2.3	3.0	2.9	1.6	1.8	1.8	3.3	<1.4
Zr	120	90	130	130	65	89	99	98	170	97	160	54	86
Hf	2.7	2.5	2.7	2.9	2.5	2.2	2.6	3.3	3.5	3.7	3.6	1.7	2.7
Nb	7.1	8.3	6.9	6.2	6.7	4.5	6.0	6.1	6.6	7.1	7.5	9.8	
Ta	.45	.44	.41	.48	.46	.35	.64	.64	.58	.59	.60	1.60	.22
Co	24.0	23.8	16.3	21.2	19.9	25.9	17.8	21.0	8.5	8.9	7.9	14.3	16.0
Li	7	8	7	4	4	6	4.0	5.0	3.0	2.0	3.0	5.0	
Ni	7.1	<10	<10	<10	<10	4.5	<10	<10	<10	<10	<10	<10	22
Cr	55.1	44.4	35.6	13.2	42.9	46.2	62.6	8.9	14.2	15.0	16.5	48.1	40.1
Sc	28.8	26.1	25.7	27.3	25.9	28.3	24.00	25.30	18.30	17.20	18.30	21.60	16.37
Mo	1.4	.86	.72	1.1	.36	.32	.42	.82	.34	.46	.44	.30	
Cu	16	<10	<10	42	12	20	40	72	32	28	32	64	7
Zn	87	77	79	78	87	65	61	77	41	47	41	70	68
Sb	<.8	.6	.5	.6	.8	1.1	.6	.7	.7	.6	.8	1.2	<1.5
Y	19	24	20	21	14	14	17	22	20	21	19	11	

Table B-3c. Rare earth element abundances in parts per million, in rocks from the Paulding Volcanic-Plutonic Complex. Analysts: R. Johnson, N.J. Rose, B. McCall, G. Sellers, J. Lindsay.

Sample No.	B.7J	B.7K	B.7H	B.7I	B.7L	B.7C	B.7G	B.7A	B.7B	B.7E	B.7D	B.7F	WG.33
La	13	22	13	13	10	7	8	8	12	13	13	13	19
Ce	23	45	22	23	18	17	15	15	29	24	27	25	33
Nd	20	30	19	17	<40	18	13	13	22	20	21	22	16
Sm	3.2	5.2	3.2	3.4	2.2	2.4	2.6	2.6	3.7	3.5	3.6	3.5	2.9
Eu	.92	1.45	.96	1.08	.63	.83	.85	.85	1.06	1.00	1.08	1.02	.63
Gd	3.3	5.7	3.4	3.8	3.0	3.2	3.3	3.3	4.3	4.5	3.8	4.7	
Tb	.59	.82	.84	.65	.66	.46	.43	.54	.54	.76	.72	.75	.72
Ho	.6	.9	.6	.65	.5	.4	.5	.5	.3	.5	.3	.5	<.6
Tm	.40	.45	.31	.47	.30	.27	.46	.46	.33	.34	.36	.34	<.53
Yb	2.4	3.3	2.6	2.5	1.9	1.6	2.1	2.1	2.7	2.6	2.8	2.7	1.3
Lu	.34	.43	.36	.36	.26	.25	.30	.30	.38	.36	.38	.37	.17

entirely comparable with data from basalts. The samples analyzed from the Paulding Complex are too low in chromium for use of such diagrams as Cr-Y plots.

All of the available geochemical data from rocks of the Paulding Volcanic-Plutonic Complex are compatible with the field evidence suggesting that the rocks of the Complex formed in an island arc environment in the Iapetos Ocean.

Ropes Creek thrust sheet

Geochemical data from 27 samples of Ropes Creek Metabasalt of the Ropes Creek thrust sheet in Georgia are given in table B-4. These data are considered an addition to the larger data-base from Ropes Creek Metabasalt (including the Ketchepedrakee, Beaverdam, Mitchell Dam, and Ropes Creek amphibolites) in Alabama presented by Stow and others (1984). We agree completely with Stow and others' geochemical assessment of these rocks and with their assignment of the rocks to an original ocean-rift environment.

The Ropes Creek Metabasalt samples (table B-4a) are low in K_2O and mostly high in TiO_2. Figure 69 is an F'MA plot of the Ropes Creek Metabasalt samples; the Ropes Creek samples fall mostly within the tholeiitic field and compare well with various Ropes Creek rocks from Alabama.

Trace element abundances in the Ropes Creek Metabasalt (table B-4b) are similar to those given by Stow and others (1984) for various amphibolites in the unit in Alabama. The Ropes Creek samples are generally low in Ba, but appear to be enriched in Sr, Zr, and Ni, somewhat enriched in Co and Cu, and greatly enriched in Cr.

Chondrite-normalized REE patterns are essentially flat (fig. 70), but most samples show slight LREE enrichment; the REE distribution patterns are quite comparable with those presented by Stow and others (1984, p. 428, fig. 6) for various amphibolites in the Ropes Creek Metabasalt in Alabama, and support the interpretation of Stow and Others that these rocks are ocean-ridge basalts.

Tectonomagmatic discrimination diagrams also indicate that the Ropes Creek Metabasalt is ancient ocean-crust. We do not have enough Zr data from samples for which we have Y or (and) Ti data to use discrimination diagrams based on these elements on the Ropes Creek Metabasalt in Georgia. On a TiO_2-Zr diagram (fig. 71a) the three Ropes Creek samples for which there are Zr data plot mostly within the ocean-floor basalt field along with the Alabama samples from Stow and others, 1984); Figure 71b shows samples of the Hillabee greenstone from Tull and others (1978) and Stow (1982) plotted on the same diagram, and figure 71c shows the various amphibolites in the Ropes Creek Metabasalt in Alabama and the Hillabee greenstone plotted with the three Georgia Ropes Creek samples on a Zr/Y-Zr diagram; most samples plot within the field of ocean-floor basalts. On a Cr-Y plot (fig. 72a) the Ropes Creek samples from Georgia plot entirely within the ocean-floor basalt field though one sample (CA.6) has anomaously low chromium (43 ppm) and 5 other samples for which Y was not determined also have low Cr abundances. Figure 72b shows the Alabama samples of various amphibolites in the Ropes Creek Metabasalt and the Hillabee greenstone (Tull and others, 1978; Stow, 1982) added to the Cr-Y diagram for the Georgia Ropes Creek samples. On an Al_2O_3/TiO_2-TiO_2 diagram (fig. 73a) the Ropes Creek samples from Georgia plot mostly in the field that includes mid-ocean ridge basalts with two samples plotting between that field and the arc field; on the same diagram the samples from various amphibolites in the Ropes Creek Metabasalt in Alabama plot mostly in the field of mid-ocean-ridge basalts (fig. 73b), as do most of the samples from the Hillabee greenstone (fig. 73c). On a CaO/TiO_2-TiO_2 diagram (fig. 74a) the Ropes Creek samples from Georgia plot mostly within the field that includes mid-ocean-ridge basalts with three samples falling between that field and a primitive or "source relatively undepleted" arc field; on

Table B-4a. Major oxide compositions and normative compositions, in weight percent, of rocks from the Popes Creek Metabasalt in the Ropes Creek thrust sheet. Analysts: J. Reid and H. Smith.

Sample No.	P.63	CA.12	CA.4	B.2	CA.14	P.326	CC.1	CH.2	CH.6	CH.3	CA.10	WG.11	CA.6	CH.4	CC.2
Major-oxide composition															
SiO_2	46.5	46.5	46.6	46.8	46.9	47.2	47.6	47.8	48.6	48.6	48.6	48.9	49.0	49.1	49.5
Al_2O_3	14.5	13.0	12.3	14.0	15.3	14.1	15.8	15.2	14.0	15.0	15.2	15.2	15.1	15.2	15.6
Fe_2O_3	6.1	3.5	2.3	4.9	1.8	4.7	3.3	4.3	2.8	4.0	3.1	3.7	2.3	3.7	2.8
FeO	8.0	8.4	8.2	8.7	8.4	5.5	7.8	7.7	5.8	8.2	7.5	8.2	8.9	8.2	7.0
MgO	6.3	5.5	7.5	8.2	8.4	8.0	8.8	7.3	11.2	7.7	8.6	7.4	9.0	7.4	8.8
CaO	11.9	15.0	13.4	9.2	10.1	11.5	11.0	9.3	13.3	8.8	11.1	9.8	9.3	9.8	13.2
Na_2O	2.5	1.7	2.8	2.8	3.3	2.6	3.2	3.4	1.3	3.0	2.6	3.2	3.1	3.2	1.8
K_2O	.13	.12	.08	.06	.15	.16	.40	.13	.07	.15	.10	.14	.11	.14	.22
H_2O+	1.2	1.2	1.5	2.8	2.2	2.5	.76	1.5	.53	1.2	1.4	.24	1.8	.24	.53
H_2O-	.47	.06	.05	1.0	.07	.13	.21	.49	.09	.71	.21	.14	.08	.14	.17
TiO_2	2.1	1.4	1.0	1.7	.87	1.4	.73	1.7	2.5	1.6	.96	1.7	1.1	1.7	.76
P_2O_5	.20	.16	.12	.23	.10	.17	.03	.19	.90	.17	.10	.22	.11	.22	.01
MnO	.15	.27	.23	.22	.21	.25	.23	.22	.16	.15	.19	.17	.20	.17	.20
CO_2	.01	3.2	4.0	.11	2.2	1.5	.01	.02	.02	.04	<.0.5	.03	<.05	.03	.03
Total	100.06	100.01	100.08	100.72	100.00	99.71	99.87	99.25	101.27	99.32	99.66	96.24	100.10	99.24	100.62
C.I.P.W. normative mineral composition															
Q	.592	5.658	.192			1.808			2.113						
C				26.191											
Z	.022			.042		.015	.006	.014	.056	.012			.010		
OR	.768	.709	.473	.355	.886	.946	2.364	.768	.414	.886	.591	.827	.650	.827	1.300
AB	21.154	14.385	23.692	23.692	27.923	22.000	22.404	28.769	11.000	25.384	22.000	27.077	26.231	27.077	15.231
AN	27.966	27.493	20.764	43.499	26.500	26.337	27.575	25.837	32.165	27.028	29.516	26.705	26.970	26.705	33.844
DI	24.076	21.051	16.019		7.368	16.081	21.650	15.345	22.040	12.397	19.862	16.499	14.747	16.438	25.337
HY	10.539	14.074	22.722	11.583	13.110	16.638		10.457	21.952	21.968	13.406	14.321	12.240	15.170	16.732
OL				13.273	12.427		16.106	6.150		.432	6.041	4.069	11.679	3.452	1.878
MT	8.844	5.075	3.335	7.105	2.610	6.815	4.785	6.235	4.060	5.800	4.495	5.365	3.335	5.365	4.060
CM	.047	.010	.039	.062	.066	.069	.067	.051	.137	.041	.070	.064	.009	.068	.071
IL	3.988	2.659	1.899	3.229	1.652	2.659	1.386	3.229	4.748	3.039	1.823	3.229	2.089	3.229	1.443
AP	.463	.371	.278	.533	.232	.394	.070	.440	2.085	.394	.232	.510	.255	.510	.023
CC	.023	7.278	9.097	.250	5.003	3.411	.023	.045	.045	.091	.114	.068	.114	.068	.068

Table B-4a continued.

Sample No.	CN.7	WG.19	CA.1	CN.10	WG.23	WG.25	WG.26	WG.27	WG.28	CN.2	WG.29	P.476
Major-oxide composition												
SiO_2	50.0	50.3	50.8	51.3	51.5	51.9	52.0	52.2	52.6	52.7	53.0	53.2
Al_2O_3	14.1	15.8	14.3	14.7	14.8	15.6	13.5	15.7	15.9	15.3	15.1	14.7
Fe_2O_3	3.2	3.5	2.9	4.8	6.7	3.5	3.5	4.4	3.6	4.6	4.4	5.2
FeO	9.5	7.6	8.5	8.2	7.0	8.9	8.6	7.1	6.3	7.4	8.8	6.5
MgO	6.7	6.7	6.9	4.7	4.7	5.7	6.4	6.2	6.6	4.1	4.5	3.8
CaO	9.4	9.1	9.5	9.1	8.0	8.1	8.5	3.6	10.3	9.3	8.4	9.8
Na_2O	3.1	3.7	3.7	1.9	4.9	4.0	4.1	4.7	1.5	3.4	3.0	2.6
K_2O	.33	.25	.16	.24	.08	.23	.08	.04	.27	.07	.25	.11
H_2O+	.82	.56	.90	1.3	.36	.50	1.1	3.0	.40	.43	.32	.68
H_2O-	.25	.39	.06	.22	.11	.03	.17	.16	.22	.11	.10	.26
TiO_2	1.2	.65	1.4	1.7	1.3	.58	1.4	.98	.55	1.1	1.0	1.7
P_2O_5	.01	.05	.17	.09	.11	.07	.21	.10	.03	.13	.12	.21
MnO	.30	.25	.21	.21	.11	.24	.19	.22	.24	.17	.24	.13
CO_2	.02	.01	.36	.03	.02	.01	.11	1.4	.02	.06	.06	.03
Total	98.93	98.86	99.86	98.49	99.69	99.36	99.86	99.80	98.53	98.87	99.29	98.92
C.I.P.W. normative mineral composition												
Q				12.066	.900		.712	8.109	10.576	7.369	8.131	13.397
C								4.852				
Z	.107			.141	.010		.022	.006		.009	.008	.017
OR	1.950	1.477	.946	1.418	.473	1.359	.473	.236	1.596	.414	1.477	.650
AB	26.231	31.308	31.308	16.077	41.461	33.846	34.692	39.769	12.692	28.769	25.384	22.000
AN	23.591	25.774	21.946	30.880	18.161	23.940	18.204	8.391	35.862	26.287	27.005	28.122
DI	18.907	15.476	17.791	11.084	16.790	13.019	17.935		12.115	15.375	11.232	15.510
HY	18.630	11.590	16.300	14.945	8.972	19.246	18.110	23.634	18.705	10.937	16.961	7.012
OL	1.569	5.878	2.523			1.073						
MT	4.640	5.075	4.205	6.960	9.714	5.075	5.075	6.380	5.220	6.670	6.380	7.540
CM	.013	.026	.042			.016	.030	.001	.011	.002	.000	.000
IL	2.279	1.235	2.659	3.229	2.469	1.102	2.659	1.861	1.045	2.089	1.899	3.229
AP	.023	.116	.394	.209	.255	.162	.487	.232	.070	.301	.278	.487
CC	.045	.023	.819	.068	.045	.023	.250	3.184	.045	.136	.136	.068

Table B-4b. Trace element abundances, in parts per million, in rocks from the Ropes Creek Metabasalt. Analysts: R. Johnson, M.J. Rose, B. McCall, G. Sellers, J. Lindsay, and L.J. Schwartz.

Sample No.	P.63	CA.12	CA.4	B.2	CA.14	P.326	CC.1	CH.2	CH.6	CH.3	CA.10	WG.11	CA.6	CH.4	CC.2
Rb	2						3	5		3		2		13	2
Ba	34			31		9	15							304	12
Sr	580			156		360	30	230	180	170		230		640	42
Cs		<2.0	<2.0	<1	<2.0		<2.0	<2	<2.0	<1.9	<2.0	<2.1		<2.0	<2.0
Th		.06		.3			<1.0	<1.3	<2.0	<1.3		<1.3		<1.3	.5
U				<.8			<2.0	<1.0	<1.0	<1.0		<1.2		<1.0	<2.0
Zr	110			210		77				58		51		130	
Hf		2.3	1.8	3.1	1.7		.75	2.6	.65	2.4	1.6	1.7	1.6	2.9	<2.0
Nb				4.3			5.7								3.8
Ta				<.7			<.5	.51		.39		.24		.59	<.70
Co	34	33.7	36.7	47.6	48.0	42	46.35	43.0	48.25	45.0	48.2	42.75	47.6	43.1	48.25
Ni	44			66		73	91	150	160	100		130	318	170	114
Cr	220	45.3	179	289	307	320	312	238.2	635.2	189.0	327	297.75	43.0	315.6	328.5
Sc		40.10	52.00	52.30	40.10		45.60	41.03	40.78	44.95	42.70	44.38	43.00	43.51	52.60
Cu				56			45	170		130		220		160	120
Zn	83	126	141	122	123		71	151	104	153	123	114.5	121	148	107
Sb				1.4			<.9	2.7	.9	<1.4		<1.4	<.9	<1.7	<2.0
Y	54		24			24	24	52	19	34	40		74		38

Sample No.	CH.7	WG.19	CA.1	CH.10	WG.23	WG.26	WG.27	WG.28	CH.2	WG.29	P.476
Rb		2			1	1	1	1	2	2	2
Ba											
Sr	530	9		130	320	190	140	110	170	280	210
Cs	<2.0	<1.6		<1.8	<1.9	<2.0	<2.1	<2.0	<2.6	<2.0	<2.0
Th	<2.1	<1.0	.5	.65	1.1	.8	.7	.85	<1.8	1.15	.95
U	<1.2	<1.2	<1.0	<1.1	<1.2	<1.3	<1.4	<1.2	<1.4	<1.3	<1.1
Zr											47
Hf	1.3	1.4	2.4	1.15	1.5	.9	2.7	1.0	1.0	1.5	1.3
Nb											
Ta		.99	<.7	.28	.16		1.18	1.60		3.40	<.70
Co	42.55	66.6	45.0	27.3	34.7	40.7	48.3	42.65	45.4	29.5	40.9
Ni	51	370		15	12	44	91	6	37	12	6
Cr	59.1	120.5	196.0	27.3	8.5	72.35	141.05	6.8	50.5	10.55	2
Sc	41.17	22.04	46.40	38.25	40.23	45.21	39.92	40.70	94.28	37.79	40.41
Cu		290			3	72	250	41	170	9	2
Zn	130.5	96	139	111.5	80.5	193.5	159.5	131.5	190.5	10.7	129.5
Sb	<1.2	<1.2		<1.1	<1.6		<1.5	<1.5	<1.5		
Y		38	22	62	50			21			

Table B-4c. Rare earth element abundances, in parts per million, in rocks from the Ropes Creek Metabasalt. Analysts: R. Johnson, N.J. Rose, B. McCall, G. Sellers, and J. Lindsay.

Sample No.	P.63	CA.12	CA.4	B.2	CA.14	P.326	CC.1	CN.2	CN.6	CN.3	CA.10	WG.11	CA.6	CN.4	CC.2
La	4		3	4	3	3.5	2	9	1	6	3	5	3	8	1.5
Ce	12	10	8	11	7	11	6.5	19	5	15	7	10	8	22	5
Nd	13	10	<20	<50	6	10	<30	17	<35	14	6	11.5	9	17	<30
Sm	5.0	2.9	21	3.4	1.9	3.5	1.4	4.7	1.0	4.2	1.9	3.0	2.2	4.7	.95
Eu	1.47	1.12	.75	1.32	.76	1.06	.50	1.36	.42	1.21	.78	.96	.80	1.36	.57
Gd	4.35	2.1	2.2	4.9	2.6	2.6					1.8		1.9		1.9
Tb	1.14	.85	.77	1.11	.51	1.14	1.6	.95	<1.57	.88	.60	.75	.57	1.21	.55
Ho	1.6	.5	.4	.9	.4	1.3	.38	.8	<.5	.6	.4	.6	.2	.9	.6
Tm	.50	.31	.22	.55	.18	.38	.8	.68	<.62	<.81	.19	.53	.23	.64	.12
Yb	4.2	<.5	2.5	4.4	2.2	2.9	.15	2.9	1.05	3.2	2.2	2.85	2.3	2.7	1.2
Lu	.63	<.06	.41	.60	.32	.45	.45	.44	.14	.50	.34	.42	.35	.36	.23

Sample No.	CN.7	WG.19	CA.1	B.4	CN.10	WG.23	WG.25	WG.26	WG.27	WG.28
La	3.5	3		10	4.5	3.5	3	5.5	4	3
Ce	7.5	7	12.6	12	10.5	7.5	6	16	9.5	8.5
Nd	<37	<25	13.7	<40	10	<37	<34	12	<38	10
Sm	2.8	.9	16.85	4.6	3.55	2.55	1.25	3.9	1.95	3.15
Eu	.94	.42	16.5	2.05	1.05	.86	.38	1.19	.68	.73
Gd		1.9	10.7	6.4						
Tb	.62	<1.11	12.98	1.45	.90	.60	<1.47	.92	.46	.73
Ho	.65	<.5	6.5	1.3	.8	.55	<.6	.75	.4	.7
Tm	.50	<.66	11.6	.74	.60	.50	<.67	.79	<.66	.84
Yb	2.75	.7	1.8	5.6	3.25	2.85	1.35	3.7	1.95	2.45
Lu	.41	.10	.29	.77	.48	.39	.20	.51	.29	.36

Sample No.	CN.2	WG.29	P.476
La	6	4.5	8
Ce	14	11	18
Nd	11.5	14	14
Sm	2.95	2.75	4.6
Eu	.96	.87	1.36
Gd			3.7
Tb	.63	.64	
Ho	.6	.5	1.4
Tm	<.66	<.64	.41
Yb	2.75	2.45	3.7
Lu	.37	.35	.56

Table B-4d. Major-oxide and normative mineral compositions, in weight percent of ultramafic rocks associated with the Ropes Creek Metabasalt. Analysts: J. Reid, H. Smith, and J. Lindsay.

Sample No.	CH.1	B.1
Major-oxide composition		
SiO_2	44.2	44.5
Al_2O_3	10.9	11.5
Fe_2O_3	6.5	2.3
FeO	6.4	8.5
MgO	15.1	18.6
CaO	9.6	6.7
Na_2O	1.4	1.1
K_2O	.07	.14
H_2O+	1.9	4.4
H_2O-	.17	.31
TiO_2	2.2	.48
P_2O_5	.42	.05
MnO	.21	.20
CO_2	.03	.25
Total	99.10	99.03
C.I.P.W. normative mineral composition		
Z	.038	.005
OR	.414	.827
AB	11.846	9.308
AN	23.256	26.033
DI	16.931	4.237
HY	23.039	27.247
OL	6.946	21.726
MT	9.424	3.335
CM	.154	.280
IL	4.178	.912
AP	.973	.116
CC	.068	.569

Table B-4e. Trace element abundances, in parts per million, in CH.1 and B.1. Analysts: L.J. Schwarz, R. Johnson, H.J. Rose, B. McCall, G. Sellers, and J. Lindsay.

Sample No.	CH.1	B.1
Rb	2	
Ba	270	
Sr	210	23
Cs	<1.7	<.8
Th	3.1	.1
U	1.1	<.6
Zr	190	23
Hf	3.6	.8
Nb	37	37
Ta	4.32	<.5
Co	75.0	88.2
Ni	660	
Cr	714.4	1300
Sc	23.90	28.3
Cu	89	
Zn	139	70
Sb		.9
Y	32	15

Table B-5f. Rare earth element abundances in parts per million, in CH.1 and B.1. Analyst: L.J. Schwarz.

Sample No.	CH.1	B.1
La	32	2
Ce	47	6
Nd	30	<40
Sm	7.7	1.2
Eu	1.30	.44
Gd		1.3
Tb	.93	.41
Ho	.7	.4
Tm	.81	.26
Yb	1.7	1.6
Lu	.23	.22

the same diagram the samples of various amphibolites in the Ropes Creek Metabasalt in Alabama plot almost entirely in the field that includes mid-ocean-ridge basalts (fig. 74b), as do most of the samples from the Hillabee greenstone (fig. 74c).

Overall, the geochemical data from the Ropes Creek Metabasalt in Georgia and Alabama support the field data indicating that the Ropes Creek is made up of oceanic crust, mostly ocean-floor basalts that originated in a mid-ocean-rift (Stow and others, 1984), the mid-Iapetus Ridge. Stow and others (1984, p. 432), following a scheme by Nisbet and Pearce (1973), suggested that different spreading rates may be deduced by different TiO_2 contents of different parts of the Ropes Creek Metabasalt in Alabama; based on that scheme, the Georgia Ropes Creek samples would mostly indicate average spreading rates (% TiO_2 average 1.29, but ranging as high as 2.5).

The Paulding Volcanic-Plutonic Complex was lumped with the Ropes Creek Metabasalt in the Ropes Creek thrust sheet (and probably some of the West Point thrust sheet as well) into various units of their New Georgia Group (abandoned - see Appendix A) by Abrams and McConnell (1981, 1984) and McConnell and Abrams (1984). The two assemblages are quite distinctive in the field, however, and comparison of geochemical data presented here also shows great differences in their chemical compositions as well as their trace element and rare earth element abundances (fig. 75). Furthermore, their original tectonic settings appear to be different based both on overall lithologic makeup and on settings suggested by plots of least mobile elements on discrimination diagrams. All of the geochemical data support the field data indicating that the Paulding Volcanic-Plutonic Complex and the Ropes Creek Metabasalt are distinctly different assemblages formed in different tectonomagmatic environments.

Soapstone Ridge thrust sheet

Geochemical data from 41 samples of rocks from the Soapstone Ridge thrust sheet in Georgia are given in table B-5; most of the samples are from the Soapstone Ridge Complex. Nearly all of the samples are high in MgO and low in alkalies (table B-5a), and whereas olivine is present in the norm in over half the samples, normative hypersthene is present in every sample. All of the Soapstone Ridge thrust sheet samples are high in Ni and Co and very high in Cr (table B-5b).

On an F'-M-A diagram (fig. 76) the altered ultramafic and mafic rocks from the Soapstone Ridge thrust sheet plot along the F'-M side of the triangle and fairly far towards M; the points have a good cluster. Figure 77 shows the Soapstone Ridge samples, the Georgia Ropes Creek samples, and two samples of ultramafic rocks associated with the Ropes Creek Metabasalt in Georgia (table B-4) plotted on an F'-M-A diagram; the trend of the points may well define a differentiation trend implying a genetic relationship between the Soapstone Ridge samples and Ropes Creek samples.

Plots of REE normalized to chondrites mostly show patterns of LREE enrichment and extreme HREE indicative of the chloritization that has affected most of the samples. Hence, REE can neither be used to confirm nor deny the interpreted ocean crust and mantle origin for the rocks of the Soapstone Ridge thrust sheet.

Table B-5a. Major oxide compositions and normative mineral compositions, in weight precent, of rocks in the Soapstone Ridge thrust sheet. Analyst: Z.A. Hamlin.

Sample No.	R.31*	R.16*	R.13*	R.15*	S.2	R.6*	R.1*	R.23*	AR.35*	R.3*	R.29*	R.8*	AR.33	R.17	R.7
Major-oxide composition															
SiO_2	42.0	42.5	42.8	43.1	43.5	44.4	44.5	44.8	44.8	44.8	44.8	45.0	45.4	46.0	46.3
Al_2O_3	11.7	5.80	6.80	6.68	11.6	6.80	6.15	7.36	7.43	7.11	8.36	5.08	5.76	8.68	6.29
Fe_2O_3	4.54	10.57	8.74	6.73	3.84	7.69	6.91	7.06	7.12	6.02	6.33	9.16	8.69	5.81	6.98
FeO	4.13	9.63	7.96	6.13	5.16	7.01	6.29	6.43	6.48	5.49	5.77	8.35	7.91	5.30	6.36
MgO	25.4	25.7	25.3	26.6	23.2	26.7	26.7	27.5	24.9	23.3	22.7	25.7	26.0	24.4	27.1
CaO	5.62	.24	.31	1.34	6.1	.45	1.75	.08	3.97	7.11	6.32	.11	.44	4.08	.43
Na_2O	.48	.59	.19	<.01	.61	.65	.16	.25	.09	.45	.5	.46	.03	1.27	.21
K_2O	.06	.03	.06	.04	.15	.04	.18	.05	<.01	.06	.11	.04	<.01	.08	.04
H_2O+					4.9										
H_2O-					.13										
TiO_2	.14	.65	.94	.61	.27	.55	.55	.36	.31	.54	.27	.43	.99	.72	.35
P_2O_5	.02	.12	.13	.14	.10	.05	.08	.01	.12	.06	.04	.11	<.01	.16	.05
MnO	.14	.27	.20	.19	.14	.26	.22	.18	.21	.20	.27	.25	.22	.23	.20
CO_2					.0										
Total	94.23	96.10	93.43	91.57	99.70	94.6	93.49	94.08	95.44	95.14	95.47	95.69	95.46	96.73	94.31
C.I.P.W. normative mineral composition															
Q			.612									.633	2.754		1.176
C	.678	4.642	6.168	4.532		4.989	2.702	6.773	.344			4.342	4.911		5.236
Z		.028	.014		.012	.020		.009	.009	.013	.006	.040	.018	.020	.008
OR	.355	.177	.355	.236	.886	.236	1.064	.295		.355	.650	.236		.473	.236
AB	4.062	4.992	1.608		5.162	5.500	1.354	2.115	.762	3.808	4.231	3.576	.254	10.746	1.777
AN	27.749	.424	.694	5.744	28.476	1.906	8.159	.332	18.933	17.207	20.246		2.183	17.752	1.816
NC												.064			
DI					.941					13.886	8.545			1.142	
HY	24.324	60.819	69.249	66.263	27.465	62.580	62.170	72.255	55.439	35.428	37.771	71.556	70.840	37.428	73.141
OL	30.186	8.225		3.561	25.366	7.084	6.703	1.339	8.619	14.451	14.207			19.027	
MT	6.583	15.326	12.672	9.758	5.568	11.135	10.019	10.236	10.323	8.728	9.178	13.281	12.600	8.424	10.120
CM	.370	.431	.487	.458	.226	.558	.528	.578	.779	.515	.478	.475	.469	.418	.624
IL	.266	1.235	1.785	1.159	.513	1.045	1.045	.684	.589	1.026	.513	.817	1.880	1.367	.665
AP	.046	.278	.301	.324	.232	.116	.185	.023	.278	.139	.093	.255		.371	.116
CC															

* Total iron reported as Fe_2O_3; Fe_2O_3 and FeO calculated using average ratio from other samples where both values were determined.

Table B-5a continued

Sample No.	R.19*	R.18*	R.12*	R.4*	R.9*	R.14*	S.547	AR.32*	R.11*	S.20	AR.37*	R.21*	R.28*	S.10	SS.RA
Major-oxide composition															
SiO_2	46.5	46.8	47.0	47.0	47.2	47.3	48.8	48.9	49.3	49.7	49.8	50.0	50.0	50.4	50.6
Al_2O_3	6.69	8.34	6.27	7.07	5.89	6.00	7.3	3.52	4.95	7.7	6.17	6.48	7.94	5.2	9.0
Fe_2O_3	7.90	6.54	6.49	5.14	6.70	7.64	6.2	6.59	7.12	4.7	4.66	5.86	4.58	7.2	3.1
FeO	7.20	5.96	5.91	4.68	6.10	6.96	5.1	6.01	6.48	4.6	4.24	5.34	4.17	4.2	5.2
MgO	25.2	24.5	26.2	22.5	26.7	25.6	21.9	25.5	26.6	15.4	27.5	23.5	23.3	27.4	15.2
CaO	1.86	1.93	2.60	8.24	.75	.84	6.8	3.91	.15	12.3	.20	3.72	5.65	1.2	13.0
Na_2O	.44	.96	.34	.45	.63	.10	.67	<.01	.07	.70	.21	.89	.62	.0	.88
K_2O	.04	.05	.05	.08	.03	.04	.20	<.01	.04	.25	<.01	.08	.07	.0	.23
H_2O+							2.1			.90				2.7	.77
H_2O-							.22			1.5				.97	.13
TiO_2	.65	.73	.29	.28	.33	.61	.37	.38	.63	.86	<.01	.62	.12	.21	.68
P_2O_5	.04	.08	.01	.06	.13	.35	.05	.17	<.01	.12	<.01	.08	.04	.06	.13
MnO	.20	.29	.26	.25	.18	.29	.21	.20	.17	.16	.14	.18	.16	.17	.18
CO_2						.01		.01				.0			.01
Total	96.72	96.18	95.42	95.75	94.64	95.73	99.92	95.20	95.52	98.89	92.95	96.75	96.65	99.71	99.11
C.I.P.W. normative mineral composition															
Q						4.932		2.405	6.365	3.442	5.365	.769		6.373	1.113
C	2.634	3.390	.949		3.769	5.125			4.517		5.431			3.162	
Z	.010	.020	.007	.008	.010	.016		.013	.007			.028	.005		.096
OR	.236	.295	.295	.473	.177	.236	1.182		.236	1.477		.473	.414		1.359
AB	3.723	8.123	2.877	3.808	5.331	.846	5.669		.592	5.923	1.777	7.531	5.246		7.446
AN	8.976	9.052	12.847	17.038	2.873	1.820	16.324	9.606	.748	17.134	1.075	13.453	18.679	5.561	19.932
NC															
DI				18.396			13.402			33.866		3.518	7.130		34.517
HY	67.441	60.341	63.082	38.744	71.661	69.658	48.641	65.771	71.526	25.924	72.361	61.128	57.166	69.968	27.634
OL	.943	3.936	5.322	9.070	.132		2.577						1.049		
MT	11.454	9.482	9.410	7.453	9.714	11.077	8.989	9.555	10.323	6.815	6.757	8.496	6.641	10.439	4.495
CM	.415	.412	.471	.519	.425	.474		.152	.352		.882	.374	.439	.399	1.291
IL	1.235	1.386	.551	.532	.627	1.159	.703	.722	1.197	1.633		1.178	.228	.139	.301
AP	.093	.185	.023	.139	.301	.811	.116	.394		.278		.185	.093		.023
CC						.023		.023							

* Total iron reported as Fe_2O_3; Fe_2O_3 and FeO calculated using average ratio from other samples where both values were determined.

Table B-5a continued.

Sample No.	S.13	AR.34*	R.20*	R.22*	AR.38*	R.25*	AR.36*	R.24	R.27
Major-oxide composition									
SiO_2	51.1	51.5	51.7	51.8	52.7	53.0	53.4	54.1	54.5
Al_2O_3	5.3	5.76	5.35	5.11	4.10	5.31	4.81	4.91	3.71
Fe_2O_3	3.4	5.60	7.22	6.97	4.33	5.70	5.07	5.81	5.49
FeO	5.8	5.10	6.58	6.34	3.94	5.19	4.61	5.30	5.00
MgO	17.1	23.5	24.7	24.4	28.5	24.0	25.2	23.5	25.6
CaO	14.1	3.72	1.12	1.10	.44	2.53	1.72	2.07	.20
Na_2O	.61	.15	.55	.41	.30	1.12	.44	.6	.21
K_2O	.05	<.01	.04	.06	<.01	.06	<.01	.06	.04
H_2O+	.52								
H_2O-	.26								
TiO_2	.76	.28	.30	.33	<.01	.37	.38	.26	.03
P_2O_5	.17	<.01	.06	.02	<.01	.05	.01	.02	.02
MnO	.20	.18	.31	.32	.15	.22	.18	.22	.28
CO_2	.02								
Total	99.39	95.81	97.93	96.86	94.49	97.55	95.83	96.79	95.08
C.I.P.W. normative mineral composition									
Q	1.431	6.278	6.590	7.817	5.819	3.791	7.879	8.817	12.198
C			2.507	2.419	2.807		.975	.143	3.006
Z		.005	.007	.006		.007	.009	.011	.004
OR	.295		.236	.355		.355		.355	.236
AB	5.162	1.269	4.654	3.469	2.538	9.477	3.723	5.077	1.777
AN	11.578	15.046	5.171	5.326	2.183	9.287	8.491	10.138	.862
NC									
DI	45.219	2.675				2.305			
HY	28.032	61.858	67.464	66.696	74.748	63.187	66.565	63.260	69.026
OL									
MT	4.930	8.119	10.468	10.106	6.278	8.264	7.351	8.424	7.960
CM	.290	.318	.579	.327	.559	.459	.587	.587	.344
IL	1.443	.532	.570	.627		.703	.722	.494	.057
AP	.394		.139	.046		.116	.023	.046	.046
CC	.045								

* Total iron reported as Fe_2O_3; Fe_2O_3 and FeO calculated using average ratio from other samples where both values were determined.

Table B-5b. Trace element abundances, in parts per million, in rocks from the Soapstone Ridge thrust sheet. Analysts: R. Lerner, N. Rait, and G.A. Wandless.

Sample No.	R.31	R.16	R.13	R.15	S.2	R.6	R.1	R.23	AR.35	R.3	R.29	R.8	AR.33	R.17	R.7
Rb											9				
Ba		84	24	52	319				110	76	120	21		38	44
Sr										27				16	
Cs	<.6	<.6	<.6	<.6	<1.0	<.7	<.5	<.6	<.7	.4	<.7	<.7	<.7	<.6	<.7
Th	<.5	.9	.8	.8	1.25	1.7	1.85	1.2	1.0	.9	.3	1.0	.8	1.85	.6
U	<.3	<.4	.3	<.6	<.7	.2	.3	.2	<.4	1.0	.2	<.6	<.4	.45	.3
Zr	<294	140	72		62	98		47	46	63	32	200	91	98	39
Hf	.2	1.25	1.7	1.4	.85	1.05	1.05	.7	.6	1.0	<.8	1.6	.7	1.75	.5
Ta	<.40	.19	.31	<.40	<.6	.31	.23	<.40	<.5	.22	<.40	.22	<.50	.28	.13
Co	90.7	120	112.0	141.0	84.3	144.5	82.5	101.1	97.0	97.75	90.9	92.5	152.0	96.6	128.0
Ni	1100	1300	1400	1300		670	630	1300	840	400	900	1400	1100	1100	1400
Cr	1720	2005	2265	2130	1050	2595	2455	2685	3620	2395	2220	2210	2180	1945	2900
Sc	10.20	14.50	13.70	12.40	12.15	15.75	13.0	12.15	20.80	16.5	27.60	13.60	12.50	17.25	11.20
Cu	38	36	32	38		59	70	38	20	64	81	250	31	16	81
Zn	73	110.5	82	76	73	90.5	90	82	78	75.5	78	109	105	95	81
Sb									1.7						
V	84	150	130	97		82	76	73	120	100	110	94	86	65	
Y	<10	19	21	19		12	15	13	21	25	22	19	22	13	

Sample No.	R.19	R.18	R.12	R.4	R.9	R.14	S.547	AR.32	R.11	AR.37	R.21	R.28	SS.RA	S.8	S.13
Rb										2					
Ba	49		72.5		6				20		31	23		180	255
Sr										260					
Cs	<.5	<.6	<.5	.4	<.5	.5		<.6	.3	<.6	<.6	<.6	<1.9	<1.0	<2.0
Th	.7	2.63	.5	.8	.95	1.3		1.0	.9	.3	4.5	<.6	.4	.4	<.9
U	.3	.65	<.5	<.5	.5	.1		.2	<.4	1.0	.5	<.4	<.5	<.8	.9
Zr	52	100	33	40	48	82		66	34		140	26	480		
Hf	.8	1.65	.4	.73	.75	1.3		1.0	.55	<.5	2.5	.6	1.3	.7	1.6
Ta	.38	.30	<.40	.36	.19	.30		.23	.22	.16	.25	<.4	.15	<.5	<.6
Co	80.0	107	97.6	99.6	72.75	79.35		77.3	89.25	114.0	83.2	72.7	52.0	31.4	47.7
Ni	1200	1200	680	550	670	820		850	880	890	870	1100	270		
Cr	1930	1915	2190	2410	1975	2205		706	1635	4100	1740	2040	1483.1	59.2	1350
Sc	14.10	11.25	9.42	15.27	10.70	12.0		11.10	13.35	7.80	23.20	19.80	47.20	22.95	56.60
Cu	39	7.5	120	35	200	81		40		120	190	6.2	4.3	86	
Zn	95	89.5	83	72	105	111.5		83	100.5	46	111	56	147.5	95.5	139.5
Sb										2.2				<.8	
V	96	71	50	78	59	77	12	65		63	46	82	93		
Y	22	13	14	16	13	25	15	16	29	36	24	25			

Table B-5b continued.

Sample No.	AR.34	R.20	R.22	AR.38	R.25	AR.36	R.24	R.27
Rb								
Ba		33				117		
Sr								
Cs	<.6	<.6	<.6	<.5	<.6	<.6	<.6	<.5
Th	.3	.4	.3	<.4	.2	.3	.7	<.5
U	.1	<.4	<.6	<.3	.2	<.5	.3	<.3
Zr	26	33	28		33	43	55	21
Hf	<.7	.5	.4	<.5	.5	.6	.55	<.5
Ta	<.40	<.4	<.4	<.40	<.4	.22	.55	.24
Co	60.0	81.6	65.4	62.4	63.05	67.1	62.5	92.0
Ni	730	420	850	740	660	760	760	1600
Cr	1480	2690	1520	2600	2135	2730	2730	1600
Sc	23.90	22.50	26.00	4.77	24.35	20.10	24.65	6.73
Cu	28	83	51	68	15	12	19	26
Zn	71	136.5	104	81	93	86	107.5	145
Sb			1.6			1.6		
V	110	68	77	34	87	83	84	37
Y	13	14	14	<10	21	78	53	19

Table B-5c. Rare earth element abundances, in parts per million, in rocks from the Soapstone Ridge thrust sheet. Analysts: G.A. Wandless and L.J. Schwarz.

Sample No.	R.31	R.16	R.13	R.15	S.2	R.6	R.1	R.23	AR.35	R.3	R.29	R.8	AR.33	R.17	R.7
La	1	10	12.5	9	8	8	9	5.5 9		25.5	7	12	5	25.5	4
Ce	3 21	25	20	13.5	19	21	12.5	13	40.5	10	27	14	45	10	
Nd	<61	1.5	14.5	5	8.5	77.5	3	5	26.5	9	15	4	24.5	<20	
Sm	.4	1.8	2.75	1.9	1.35	.9	1.6	.8	1.6	5.55	2.3	2.9	1.1	3.95	.7
Eu	.19	.34	.44	.34	.41	.13	.33	.16	.39	1.80	.55	.48	.19	.96	.22
Gd	<2	1.25	1.9	.5	1.2	<2	1.25	<2	1.5	4.1	2.1	2.5	<3.0	3.5	<3
Tb	.12	.17	.35	.28	.15	.09	.22	.10	.24	.81	.48	.30	.08	.42	.08
Ho	<.3	.2	.3	<.8	<.2	<.5	.2	<.4	.2	.5	.4	<.7	<.4	<.9	<.6
Tm	<.10	.09	.09	.06	.07	.03	.07	.04	.14	.26	.30	.04	.05	.17	<.2
Yb	.3	.6	.85	.6	.55	.35	.5	.3	.9	1.7	2.5	.8	.4	1.25	.3
Lu	.06	.10	.14	.11	.08	.05	.09	.05	.15	.22	.37	.11	.06	.19	.06

Sample No.	R.19	R.18	R.12	R.4	R.9	R.14	S.547	AR.32	R.11	AR.37	R.21	R.28	SS.RA	S.8	S.13
La	3	15.5	7	35.6	16	12		20	4	1	61	61	26	10	10
Ce	9	33.5	11	60.7	22	26		27	10	4	54	54	28	18.5	18.5
Nd	<20	15	8	38	12	11.5		22	3	<6	53	53	28	11.5	17
Sm	1.0	2.55	1.2	7.6	1.9	1.8		4.2	.7	.2	10.1	10.1	5.2	2.25	4.25
Eu	.10	.55	.30	3.32	.39	.26		.70	.08	.03	2.67	2.67	1.00	.84	1.02
Gd	.8	2.05	<2.0	6.2	1.3	1.6		3.2	.9	<2.0	10.2	10.2	4.2	1.75	2.75
Tb	.12	.24	.13	1.02	.22	.21		.61	.06	<.3	1.20	1.20	.77	.32	.81
Ho	.3	<.7	<.7	.63	<.6	<.7		.5	<.5	<.4	.6	.6	.1	.2	.5
Tm	.04	.12	.08	.23	.09	.08		.23	.04	<.1	.40	.40	.36	.11	.19
Yb	.4	.7	.4	1.86	.7	.7		1.5	.15	.1	2.8	2.8	2.4	1.0	1.75
Lu	.08	.12	.07	.25	.10	.12		.22	.04	.02	.34	.34	.35	.15	.26

Sample No.	AR.34	R.20	R.22	AR.38	R.25	AR.36	R.24	R.27
La	2	4	4	1	10	84	32.5	11
Ce	5	101.5	12	3	22.5	69	19.5	13
Nd	<7	6	7	<6	16	77	36.5	12
Sm	.6	1.9	1.5	.2	2.4	15.1	8.6	2.1
Eu	.18	.44	.38	.03	.50	3.83	1.78	.36
Gd	<2.0	1.1	1.0	<2.0	2.5	17.7	9.4	2.1
Tb	<.3	.33	.24	<.2	.33	2.71	1.60	.33
Ho	<.4	<.6	<.9	<.4	<.6	2.0	1.05	.2
Tm	.02	.14	.14	<.08	.11	1.13	.69	.12
Yb	.4	1.15	.8	.2	1.25	8.2	5.2	.8
Lu	.08	.16	.16	.03	.18	1.12	.77	.12

FIGURE CAPTIONS

Figure 4. a. Present known distribution of autochthogenetic rocks (blue) and allochthogenetic rocks (red) in the southernmost Appalachians. Granitic plutons in the Little River thrust stack are colored red with the allochthogenetic rocks. Granitic plutons in the areas of autochthogenetic rocks are colored pink because, though probably formed from anatectic melting, some were probably derived from the allochthogenetic rocks.

b. Present known distribution of the Bill Arp thrust sheet in the southernmost Appalachians.

b. Present known distribution of Grenville basement in the southernmost Appalachians.

Figure 5. Generalized geologic map of the northwestern part of the Atlanta, Georgia 1° x 30' quadrangle showing attitudes and facing of graded beds in the Bill Arp Formation in the Austell-Frolona anticlinorium. Each symbol represents locality where four or more graded beds give facing direction. Dips are averaged and rounded. See text for further explanation.

Figure 6. Graded bedding in metagraywacke and schist of the of the Bill Arp Formation in the Austell-Frolona anticlinorium.

a. Small cut on south side of Mason Creek Road just east of Baggett Road, in the Winston, Georgia 7.5 min. quadrangle. Sharp bases and diffuse tops of metagraywacke beds indicate tops to the north (right in photo); beds are near vertical. Knife is 8 cm long.

b. Closer view of some of the beds shown in a. Arrows point to sharp bases of coarser parts of beds (tops to right). Number 2 is 2 cm high.

c. Cut along Johnston Road, approximately 30 meters southeast of powerlines, in the Winston, Georgia 7.5 min. quadrangle. Sharp bases and diffuse tops indicate that tops are to the north (right in photo). Coin is U.S. nickel, 2 cm in diameter.

d. Exposure in ditch along unnamed dirt road just north of Hinesley Cemetary about 20 meters east of tributary to Little Snake Creek in the Hulett, Georgia 7.5 min. quadrangle. Tops toward top of photo (to southeast). Coin is U.S. nickel, 2 cm in diameter.

e. Roadcut along Mason Creek Road between powerlines and Berea Road in the Winston, Georgia 7.5 min. quadrangle. Tops of beds toward top of photo. Knife is 8 cm long.

Figure 7. a. Deformed calcareous concretions in younger (upper) facies of the Bill Arp Formation in the Austell-Frolona anticlinorium. Roadcut along westbound lanes of Interstate 20 just west of Georgia Highway 5, in the Winston, Georgia 7.5 min. quadrangle. Concretion near center of photo is approximately 1 meter long.

b. Closer view of part of the same cut. Concretion in lower left corner of photo is the same as the one under the hammer in a.

Figure 10. Metamorphosed felsic tuff from the Cherokee open-pit mine of the Tennessee Chemical Company, Ducktown, Tennessee. Dark minerals are amphiboles. Knife is 6 cm long. Figure 11. Metamorphosed tuff breccia from the Cherokee open-pit
mine of the Tennessee Chemical Company, Ducktown, Tennessee. Knife is 6 cm long.

Figure 12. Metavolcanic-epiclastic conglomerate in core from 364 meters (1193 feet) below surface in the Cherokee underground mine of the Tennessee Chemical Company, Ducktown, Tennessee (courtesy of W. Randy Slater).

Figure 13. Present Known distribution of the Zebulon thrust sheet in the southernmost Appalachians. Figure 14. Exotic block of amphibolite (A) in schist of the Zebulon Formation in cut along U.S. Highway 29 0.75 kilometer southwest of the Grantville City Limits in the Grantville, Georgia 7.5 min. quadrangle. Figure

Figure 15. Present known distribution of the Clairmont thrust sheet in Georgia and Alabama.

Figure 16. Blocks in the Clairmont melange.

a. Exotic block of amphibolite in the Clairmont melange. Folds and foliation in the amphibolite block do not pass into the matrix. A block of light gray granofels (G) is just beneath the Amphibolite block. Roadcut at corner of Clairmont Road and exit ramp from northbound lanes of Interstate 85 in the Northeast Atlanta, Georgia 7.5 min. quadrangle. Knife below amphibolite block is 8 cm long.

b. Exotic clast of folded amphibolite and light-gray granofels in the Clairmont melange. Same outcrop

as figure 10. The clast is a lithic match of rocks in the Promised Land Formation (see fig. 26). Knife is 8 cm long.

c. Exotic block of light-gray, equigranular biotite granitic gneiss in the Clairmont melange. Roadcut along southbound lanes of Interstate 85 just south of Monroe Drive in the Northeast Atlanta, Georgia 7.5 min. quadrangle. Large block is approximately 2 meters long.

d. Quartzite block in scaly schistose matrix. Same outcrop as c.

Figure 17. a. Clairmont melange in same outcrop as figure 10 showing autoclasts (native blocks; AU for example). Folds and S-planes in the autoclasts terminate against the matrix. A small clast of light gray granofels is seen in the left-center of the photo; this clast is approximately 1 meter long.

b. Large exotic block of amphibolite (A) showing folds terminating against Clairmont melange matrix. Roadcut at Buford Highway (U.S. Highway 23) and North Druid Hills Road, in the Northeast Atlanta, Georgia 7.5 min. quadrangle. Figure 18.

Figure 18. Structurel styles in the Clairmont melange.

a. Clairmont melange in outcrop near intersection of East Atlanta Road and Gas Plant Road, Stockbridge, Georgia 7.5 min. quadrangle, showing amphibolite clast in streaky biotite-plagioclase gneiss matrix. Note brittle deformation of the amphibolite clast and ductile deformation of the matrix. Dark part of clast is approximately 0.3 meters thick.

b. Ripped-apart block of nearly white granofels in scaly Clairmont melange. Same outcrop as 16c.

c. Nearly white granofels pulled apart in scaly Clairmont melange. Same outcrop as b.

d. Block of light-gray granofels boudinaged in Clairmont melange. Same outcrop as b. Dark spot in left of photo is tar.

Figure 19. Present known distribution of the Wahoo Creek thrust sheet in the southernmost Appalachians.

Figure 20. a. Slabby weathering gneiss of the Wahoo Creek Formation along Briarcliff Road, about 0.3

kilometer north of North Druid Hills Road in the Northeast Atlanta, Georgia 7.5 min. quadrangle.

b. Closeup of same outcrop as a, showing finely laminated texture.

Figure 21. Finely laminated, metamorphosed calcareous tuff of the Wahoo Creek Formation containing thin calc-silicate laminae (light colored laminae) and thin epidote-amphibolite (dark) layers. Large block blasted for construction of parking lot of Brownings Resturant, approximately 1 kilometer south of U.S. Highway 29, on east side of Mountain Industrial Blvd., in the Norcross, Georgia 7.5 min. quadrangle. Knife is 8 cm long.

Figure 22. Present known distribution of the Atlanta thrust sheet in the southernmost Appalachians.

Figure 23. a. Laminated, metamorphosed calcareous tuff of the Ison Branch Formation in roadcut along Futral Road approximately 2 kilometers southeast of the Central of Georgia Railroad in the Orchard Hill, Georgia 7.5 min. quadrangle.

b. Layered, metamorphosed calcareous tuff of the Ison Branch Formation in roadcut along Georgia Highway 16, at corner of first road past Griffin, Georgia City Limits, in the Luella, Georgia 7.5 min. quadrangle.

Figure 24. a. Chaotic fold patterns in laminated, metamorphosed calcareous tuff of the Ison Branch Formation in cut along Hill Street just north of U.S. Highway 19/41 Business, in the Griffin South, Georgia 7.5 min. quadrangle. Knife is 8 cm long.

b. Closer view of part of same cut as a.

c. Closer view of part of same cut as a.

Figure 25. Present known distribution of the Promised Land thrust sheet in the southernmost Appalachians.

Figure 26. Interlayered mafic and felsic tuffs of the Promised Land Formation in outcrop behind topless bar behind shopping center at Stewart Road and Cleaveland Avenue, in the Southwest Atlanta, Georgia 7.5 min. quadrangle. These rocks are lithic matches of some blocks in the Clairmont melange (see fig. 16b). Three generations of folds are seen in this outcrop; the two axial traces marked B and K are the "Buck Branch" and "Klondike" generations of Atkins and Higgins (1980), or F_1 (B) and F_2 (K).

Figure 27. Present known distribution of the Sandy Springs thrust sheet in the southernmost Appalachians.

Figure 28. a. Sandy Springs thrust fault separating moderately dipping gneiss and amphibolite of the Clairmont melange from Chattahoochee Palisades Quartzite in the Sandy Springs thrust sheet. Barrow pit on south side of Georgia Highway 138 just east of Stockbridge City Limits in the Stockbridge, Georgia 7.5 min. quadrangle. View is approximately 12 meters long.

b. Closer view of the fault; same outcrop as a.

c. Closer view of the fault showing minor drag-folding (D) in the rocks immediately beneath the fault and finely laminated weathering of very thin zone of sheared quartzite (S). Same outcrop as a.

Figure 29. Present known distribution of the Paulding thrust sheet in the southernmost Appalachians.

Figure 30. Typical exposure of the Paulding Volcanic-Plutonic Complex. Cut along Vaughn Road 0.3 kilometers south of Georgia Highway 92, in the Brooks, Georgia 7.5 min. quadrangle. K-feldspar-poor granitic dike (F) has the same foliation as the chloritic, epidotic, amphibolite and granofels it has intruded, whereas more "normal" granitic dikes (C) crosscut the foliation. Typical thin layer of "hardpan" (not visible in photo) caps the cut.

Figure 31. Present known distribution of the West Point thrust sheet in the southernmost Appalachians.

Figure 32. Amygdular metabasalt of the Ropes Creek Metabasalt in the small slice of Ropes Creek thrust sheet that rests atop the West Point melange at Marblehill, Georgia. Light spots on rocks are lichen stains; holes are filled amygdules that have weathered out to resemble vesicles. Sample from outcrops between the southwestward flowing tributary to the East Branch of Long Swamp Creek and the third unpaved road to the to the northeast from Georgia Highway 53 southeast of the town of Marblehill, in the Nelson, Georgia 7.5 min. quadrangle.

Figure 33. Clast of ultramafic rock in scaly schist of the West Point melange. Barrow pit just east of stream along the north side of the first dirt road running east just south of the School in Marblehill, in the Nelson, Georgia 7.5 min. quadrangle.

Figure 34. a. Block of eclogite-bearing amphibolite (under hammer handle) in highly sheared talcose and chloritic

matrix, in outcrop along the northern shore of Lake Chatuge just southeast of Bell Creek Church, in the Hiawassee, Georgia-North Carolina 7.5 min. quadrangle. Hammer is long-handled model.

b. Highly deformed amphibolite containing small clasts of eclogite (arrows point to two of the eclogite clasts). West Point melange along the northern shore of Lake Chatuge just south of Lower Bell Creek Church, in the Hiawassee, Georgia-North Carolina 7.5 min. quadrangle. Coin is U.S. penny, 1.4 cm in diameter.

Figure 35. Highly sheared talc-chlorite-actinolite schist with small olivine grains; matrix of the West Point melange. Note several shear-plain orientations. Same outcrops as fig. 34b. Coin is U.S. quarter, 2.3 cm in diameter.

Figure 36. Blocks of eclogites and mafic rocks in the West Point melange.

a. Block of eclogite in sheared amphibolite matrix in cut behind trailer home on north side of Lower Bell Creek Church Road 0.5 kilometers west of Georgia Highway 75, in the Macedonia, Georgia-North Carolina 7.5 min. quadrangle. Hammer is long-handled model.

b. Knockers of eclogite and ultramafic rocks in sheared amphibolite matrix in hillside just west of Lake Chatuge southwest of Bell Creek Church in the Hiawasse, Georgia 7.5 min quadrangle.

c. Block of coarse grained mafic rock in a chlorite-actinolite matrix in the West Point melange along the eastern shore of West Point Lake, approximately 2 kilometers northeast of West Point Dam (this is "type locality" of the West Point melange), in the Opelika, Alabama-Georgia, 1:100,000 scale quadrangle (the location is on the Lanett North, Georgia-Alabama 7.5 min. quadrangle, but the dam was built after the 1964 quadrangle). Figure 37. a. Large knocker of eclogite-bearing amphibolite in a highly sheared talc-actinolite-chlorite matrix in the West Point melange. Arrow points to one of the abundant eclogite clasts or clots. Hammer is long-handled model. Outcrop on small peninsula just southeast of Bell Creek Church, in the Hiawassee, Georgia-North Carolina 7.5 min. quadrangle.

b. Same outcrop as a. showing sheared nature of the melange matrix. The eclogite knocker is labeled E.

c. More typical occurrence of eclogite-bearing amphibolite knockers in the hillside southwest of Bell Creek Church (see above).

Figure 38. a. Block (from matrix of highly sheared talc-actinolite-chlorite schist) of highly deformed amphibolite containing clasts of eclogite - arrows point to three eclogite clasts. The amphibolite has the macrotexture of mylonite, but is recrystallized in thin section. Knife is 6 cm long.

b. Close view of some of the eclogite clasts in the amphibolite block shown in a. (Photo by Dean B. Radtke)

c. Very close view of one of the larger eclogite clasts in the amphibolite block shown in a, showing "flow" of the amphibolite "layers" around the clast. (Photo by Dean B. Radtke)

d. Closer view of same eclogite clast as in c, showing its composition of light-colored pyroxenes (P) and darker garnets (G). See text and Dallmeyer (1974) for more details on the eclogites.

Figure 39. Present known distribution of the Ropes Creek thrust sheet in the southernmost Appalachians.

Figure 40. Pillow basalts in the Ropes Creek Metabasalt in outcrops along east side of the Flint River just upstream from Hampton Road, in the Fayetteville, Georgia 7.5 min. quadrangle. Most of these outcrops have been moved a few meters during construction of water-treatment facilities nearby. Before they were disturbed Y's of adjacent pillows indicated they were right-side-up. The metabasalts are extensively epidotized and chloritized.

a. Close-packed, essentially undeformed pillows.

b. Deformed pillows.

Figure 41. Iron formations in the Ropes Creek metabasalt.

Figure 42. Highly deformed magnetite-garnet-chlorite schist from "Garnet Hill" alteration zone in outcrop at Mill Creek and north-south running road about 1.3 kilometers southeast of where the Seaboard Railway crosses over the Southern Railway, in the Dallas, Georgia 7.5 min. quadrangle (also see fig. 3).

Figure 43. Present known distribution of the Soapstone Ridge thrust sheet in the southernmost Appalachians. Some of the smaller occurrences have been exaggerated on this map.

Figure 44. Soapstone Ridge thrust fault at the base of the Soapstone Ridge thrust sheet in large cut behind Old Dominion Truck Lines Depot at Moreland Avenue and the South River in the Southeast Atlanta, Georgia 7.5 min. quadrangle. Rocks above the thrust are altered metapyroxenites of the Soapstone Ridge Complex; there is a thin layer of highly sheared and altered dunite or peridotite (now talc-chlorite-actinolite schist) about 2 meters thick at the base of the Soapstone Ridge sheet in this cut (it doesn't show in this photo). Rocks below the thrust fault are metamorphosed felsic tuffs with thin layers of amphibolite belonging to the Promised Land Formation. Folds and pegmatite dikes in the Promised Land rocks are cut-off abruptly at the fault. View is approximately 20 meters wide.

Figure 45. Slices of Soapstone Ridge thrust sheet structurally emplaced with Corbin Gneiss in the Allatoona Complex of Grenville basement and the Pinelog Formation of the Ocoee Supergroup in the Fort Mountain area, Georgia.

a. New talc prospect on the west face of Fort Mountain, in the Crandall, Georgia 7.5 min. quadrangle. Corbin Gneiss (C) rests overturned in sharp fault contact (Soapstone Ridge thrust fault) upon talc and serpentinite (T) of the Soapstone Ridge thrust sheet. Arrow points to man for scale. Conglomerates of the Pinelog Formation crop out a few meters above the view in the photo.

b. Massive greenstones in the same talc prospect (this view is adjacent on the right (south) to the view in a. It is not known whether these greenstones are metabasalts within the Soapstone Ridge thrust sheet or Ropes Creek Metabasalt in the Ropes Creek thrust sheet.

c. Highly sheared Corbin Gneiss in entrance road to same prospect as a and b - about 50 meters south view in b. Arrows point to euhedral K-feldspars that have survived the shearing. Most K-feldspar crystals have been deformed into white streaks. (Compare with fig. 63).

Figure 47. a. Reddish-pink and white ribbon tuffaceous metacherts interbedded with scaly schist composed of manganiferous mica and amphiboles in the Potato Creek slice of the Macon melange in a roadcut along Wesleyan Circle, 0.5 kilometer from Wesleyan Drive in the Macon Northwest, Georgia 7.5 min. quadrangle. Note numerous structural disruptions to bedding. Hand-lens is 2.5 cm in diameter.

b. Eraratic structural features in metamorphosed pebbly mudstone and graywacke conglomerate that forms the Potato Creek slice of Macon melange in cut along unnamed road approximately 1 kilometer south of Mt. Pleasant Church (South Carolina), in the Chennault, Georgia-South Carolina 7.5 min. quadrangle.

c. Potato Creek slice of the Macon melange in same roadcut as a. Melange matrix here is scaly schist composed of manganiferous mica and amphiboles, with interbedded tuffaceous metacherts. Angular block and rounded clast below it are metagabbro.

d. Folded clast of tuffaceous metachert in matrix of scaly schist interbedded with tuffaceous metacherts. Same outcrop as a.

Figure 47. e. Metamorphosed pebbly mudstone of the Potato Creek slice of the Macon melange in roadcut along Po Biddy Road just south of Potato Creek in the Lincoln Park, Georgia 7.5 min. quadrangle. The isoclinal (elasticas) fold is discordant to the surrounding matrix. Knife is 8 cm long.

f. Closeup of same fold as in a. Round, undeformed pebbles are quartz, quartzite, micaceous quartzite, and quartz-feldspar rock. Faint cleavage is not parallel to the axial-plane of the fold. The highest grade minerals found in the matrix are biotite and garnet. Fold is interpreted to result from soft-sediment deformation during imbrication of the melange wedge. Knife is 8 cm long.

g. Closeup of typical metamorphosed pebbly mudstone matrix in same outcrop as e.

Figure 48. a. Same outcrop as figure 47e, showing numerous structural discontinuities common in the melange. Lighter rocks are metamorphosed pebbly mudstones; darker rocks are amphibolite blocks (clasts).

b. Same outcrop as Figure 47b, showing erratic structural discontinuities. Clasts of chloritic amphibolite is above coin. Coin is U.S. penny, 1.9 cm in diameter.

c. Same outcrop as b, showing erratic structural patterns and numerous clasts.

d. Same outcrop as 47a, showing numerous structural discontinuities. Clasts are metatuffaceous chert (C) and metagabbro (G).

e. Structural discontinuities in metamorphosed pebbly mudstones and metagraywackes of the Juliette slice of the Macon melange. Roadcut along first unpaved road to the west from U.S. Highway 23 north of St. Peters Rock Church on east side of the east fork of Rum Creek in the East Juliette, Georgia 7.5 min. quadrangle.

Figure 49. a. Block of metapyroxenite in pebbly mudstone matrix of the Juliette slice of the Macon melange. Same outcrop as Figure 48e.

b. Pebbly mudstone of the Juliette slice of the Macon melange in same outcrop as Figure 47b.

c. Closer view of b, showing undeformed, finely laminated, barely metamorphosed pebble of Little River allochthon argillite in scaly semischist matrix of pebbly mudstone. Clasts of various other rock types are also visible in this photograph. Same outcrop as Figure 47b.

d. Block of metachert in scaly semischist and metamorphosed pebbly mudstone. same outcrop as b.

e. Calc-silicate clasts in metamorphosed pebbly mudstone of the Juliette slice of the Macon melange. Same outcrop as b. Lens-cap is 5.5 cm in diameter.

f. Small rounded clast of altered ultramafic rock (beneath coin) in metamorphosed pebbly mudstone of the Juliette slice of the Macon melange. Many clasts of different rock types are visible in this photo. Same outcrop as b. Coin is U.S. penny, 1.4 cm in diameter.

Figure 49. g. Large slab of high-grade metavolcanic gneisses in the Juliette slice of the Macon melange in the Kiokee antiform. Roadcut along Georgia Highway 104, approximately 2.4 kilometers southeast of Pollards Corner, in the Appling, Georgia 7.5 min. quadrangle.

h. Rounded clast of quartzite in the Juliette slice of the Macon melange in the Kiokee antiform in cut along Interstate 20, approximately 6.5 kilometers east of Georgia Highway 150, in the Winfield, Georgia 7.5 min. quadrangle.

Figure 50. Generalized geologic map of the Gladesville-Juliette area in central Georgia, showing the major mafic "bodies" as depicted by Matthews (1967), Prather (1971), Carpenter (1971), and Georgia Geological Survey (1976). Compare with figure 51.

Figure 51. Generalized geologic map of the Gladesville-Juliette area in central Georgia showing large mafic clasts and aggregates of mafic clasts as depicted by our mapping. Compare with figure 50.

Figure 52. Rounded clast of metagabbro in the Macon melange in same outcrop as Figure 47a. Melange matrix schistosity passes concordantly around the clast, whereas faint mineral alignment in the clast is oriented almost normal to the schistosity of the matrix, thus mimicking the structural relations between the melange matrix and large mafic and mafic-ultramafic bodies in the melange. Clast is approximately 20 cm long.

Figure 53. Centimeter-scale, disrupted igneous layering in a mafic slab. Roadcut along the east side of Georgia Highway 83, 1.4 kilometers northeast of Gladesville, Georgia in the Berner, Georgia 7.5 min. quadrangle. Hand-lens is 2.5 cm in diameter.

Figure 54. a. Finely laminated, chloritic, graphitic, and pyritic marble in the Po Biddy slice of the Macon melange. Hammer rests on chlorite schist lense; amphibolite lenses are also present in the marble. Vulcan Materials Grover quarry off frontage road for Interstate 85 in the Grover, North Carolina-South Carolina 7.5 min. quadrangle.

b. Closer view of slab of marble from the same quarry showing fine laminations. Knife is 8 cm long.

c. Very close view of slab in b, showing recrystallized nature of the laminae.

Figure 56. Dark graptolitic Middle Ordovician Rockmart Slate resting in sharp contact upon Middle Ordovician Lenoir Limestone.

a. In abandoned quarry 0.6 kilometer north-northeast of Portland, Georgia, in the Rockmart North, Georgia 7.5 min. quadrangle. Quarry face is approximately 30 meters high.

b. In cuts leading to abandoned quarry about 400 meters northeast of where Marquette Road crosses the Seaboard Coast Line Railroad east of Georgia Highway 101, in the Rockmart North, Georgia 7.5 min. quadrangle.

Figure 55. Polymictic conglomerate from the Tellico Formation above the Rockmart Slate, from cut of the Seaboard Coast Line Railroad east of the overpass on U.S. Highway 278. Photograph by Charles W. Cressler.

Figure 57. Diagram illustrating interpreted approximately along-strike changes in the Tellico-Talladega clastic wedge. (see text for further explanation)

Figure 58. a. Fault zone of the Carters Dam fault in construction cuts for the spillway below Carters Dam, in the Oakman, Georgia 7.5 min. quadrangle. b shows scale.

b. Closer view of the main tectonic melange gouge zone of the Carters Dam fault at same locality as a. The main tectonic melange gouge zone is the dark zone to right of man; light rocks to left of man belong to the Cambrian Conasauga Formation (trilobites have been collected from the Conasauga a few meters from this view); rocks to right of dark zone are an autoclastic melange composed of clasts of widely varying size of Ocoee Supergroup metaconglomerates. Arrows point to native blocks in tectonic melange zones on both sides of the main tectonic melange gouge.

c. Highly deformed Ocoee metagraywacke and conglomerate in Carters Dam spillway cut approximately 15 meters east (to right of) the view in a.

Figure 59. Major groups of granitic plutons in the southernmost Appalachians.

Figure 60. a. Xenoliths of Bill Arp Formation metagraywackes in Austell Gneiss. Arrow points to xenolith that has partially become a "ghost." Knife on largest xenolith is 8 cm long. Outcrop on north side of eastbound lanes of Interstate 20, 2 kilometers west of Georgia Highway 5, in the Winston, Georgia 7.5 min. quadrangle.

b. Texture of Austell Gneiss a few meters away from xenoliths. Same outcrop as a.

c. Protoclastic texture of Austell Gneiss developed at contact with large xenolith in same outcrop as a. Texture is interpreted to result from "freezing" of the moving Austell magma as it came into contact with the cooler xenolith.

Figure 61a-o. Schematic diagrams illustrating the evolution of the southernmost part of the Appalachian orogen, Georgia and Alabama.

Figure 62. Map showing the Indonesian region and the Appalachian region at the same scale.

Figure 63. Sheared Grenville basement gneiss in the Pine Mountain anticlinorium. Arrow points to euhedral K-feldspar that has survived the shearing - most K-feldspar crystals have been sheared and deformed. Gneisses such as this have previously been mapped as part of the Sparks Schist; this is in error, because the rock in the photo is clearly derived from shearing of the basement gneiss. Roadcut at corner of first road to the left (east) south of Pine Mountain and Georgia Highway 354, in the Pine Mountain, Georgia 7.5 min. quadrangle.

Figure 64. Map showing the location of the type section of the Paulding Volcanic-Plutonic Complex.

Figure 65. Data from rocks of the Paulding Volcanic-Plutonic Complex plotted on an F'-M-A diagram (F'= Total iron as FeO). Data from the "Hillabee" dacites (Tull and others, 1978; Stow, 1982) are also plotted. The line marked by TH/CA represents the boundary between tholeiitic and calc-alkaline rocks (from Irvine and Baregar, 1971; Stow and others, 1984).

Figure 66. Chondrite-normalized rare-earth element distribution patterns for rocks from the Paulding Volcanic-Plutonic Complex.

Figure 67. a. Data from rocks of the Paulding Volcanic-Plutonic Complex plotted on a Ti-Zr diagram for tectonomagmatic discrimination (after Pearce and Cann, 1973).

b. Data from rocks of the Paulding Volcanic-Plutonic Complex plotted on a TiO_2-Zr diagram for tectonomagmatic discrimination (after Pearce, 1979).

c. Data from rocks of the Paulding Volcanic-Plutonic Complex plotted on a Hf-Ta-Th diagram for tectonomagmatic discrimination (after Wood, 1980).

Figure 68. a. Data from rocks of the Paulding Volcanic-Plutonic Complex plotted on an Al_2O_3/TiO_2 diagram for tectonomagmatic discrimination (as modified by Stow and others, 1984, from Sun and Nesbitt, 1978).

b. Data from rocks of the Paulding Volcanic-Plutonic Complex plotted on a CaO/TiO_2-TiO_2 diagram for tectonomagmatic discrimination (as modified by Stow and others, 1984, from Sun and Nesbitt, 1978).

Figure 69. a. Data from the Ropes Creek Metabasalt in Georgia plotted on an F'-M-A diagram. The line marked by TH/CA represents the boundary between tholeiitic and calc-alkaline rocks (Irvine and Barager, 1971; Stow and others, 1984).

b. Data from the Ropes Creek Metabasalt in Georgia and Alabama, including Ropes Creek, Ketchepedrakee, Mitchell Dam, and Beaverdam amphibolites (Stow and others, 1984) plotted on an F'-M-A diagram.

c. Data from the Ropes Creek Metabasalt in the Hillabee greenstone (Tull and others, 1978; Stow, 1982) plotted on an F'-M-A diagram.

Figure 70. Chondrite-normalized rare-earth element distribution patterns for the Ropes Creek Metabasalt in Georgia (compare with Stow and others, 1984, p. 428).

Figure 71. a. Data from the Ropes Creek Metabasalt in Georgia and Alabama, including the Ropes Creek, Ketchepedrakee, Mitchell Dam, and Beaverdam amphibolites (Stow and Others, 1984), plotted on a TiO_2-Zr tectonomagmatic discrimination diagram (after Pearce, 1979).

b. Data from the Hillabee greenstone (Tull and others, 1978; Stow, 1982) plotted on a TiO_2-Zr tectonomagmatic discrimination diagram (after Pearce, 1979).

c. Data from the Ropes Creek Metabasalt in Georgia and Alabama, including the Ropes Creek, Ketchepedrakee, Mitchell Dam, and Beaverdam amphibolites, and the Hillabee greenstone (Tull and others, 1978; Stow, 1982; Stow and others, 1984).

Figure 72. a. Data from the Ropes Creek Metabasalt in Georgia plotted on a Cr-Y tectonomagmatic discrimination diagram (after Pearce, 1979, and Gale and Pearce, 1982).

b. Data from the Ropes Creek Metabasalt in Georgia and Alabama, including the Ropes Creek, Ketchepedrakee, Mitchell Dam, and Beaverdam amphibolites, and the Hillabee greenstone (Tull and others, 1978; Stow, 1982; Stow and others, 1984), plotted on a Cr-Y tectonomagmatic discrimination diagram (after Pearce, 1979, and Gale and Pearce, 1982).

Figure 73. a. Data from the Ropes Creek Metabasalt in Georgia plotted on an Al_2O_3/TiO_2-TiO_2 tectonomagmatic discrimination diagram (as modified by Stow and others, 1984, from Sun and Nesbitt, 1978).

b. Data from the Ropes Creek Metabasalt in Alabama (Stow and others, 1984) plotted on an Al_2O_3/TiO_2-TiO_2 tectonomagmatic discrimination diagram as modified by Stow and others, 1984, from Sun and Nesbitt, 1978).

c. Data from the Hillabee greenstone (Tull and others, 1978; Stow, 1982) plotted on an Al_2O_3/TiO_2-TiO_2 tectonomagmatic discrimination diagram as modified by Stow and others, 1984, from Sun and Nesbitt, 1978).

Figure 74. a. Data from the Ropes Creek Metabasalt in Georgia plotted on a CaO/TiO_2-TiO_2 tectonomagmatic discrimination diagram (as modified by Stow and others, 1984, from Sun and Nesbitt, 1978).

b. Data from the Ropes Creek Metabasalt in Alabama (Stow and others, 1984) plotted on a CaO/TiO_2-TiO_2 tectonomagmatic discrimination diagram (as modified by Stow and others, 1984, from Sun and Nesbitt, 1978).

c. Data from the Hillabee greenstone (Tull and others, 1978; Stow, 1982) plotted on a CaO/TiO_2-TiO_2 tectonomagmatic discrimination diagram (as modified by Stow and others, 1984, from Sun and Nesbitt, 1978).

Figure 75. Average chondrite-normalized rare-earth element distribution patterns for the Ropes Creek Metabasalt in Georgia (RC) and the Paulding Volcanic-Plutonic Complex (P).

Figure 76. Data from rocks of the Soapstone Ridge thrust sheet plotted on an F'-M-A diagram. The line marked by TH/CA represents the boundary between tholeiitic and calc-alkaline rocks (after Irvine and Barager, 1971; Stow and others, 1984).

Figure 77. Data from rocks of the Soapstone Ridge thrust sheet, the Ropes Creek Metabasalt in Georgia, and ultramafic rocks associated with the Ropes Creek Metabasalt plotted on an F'-M-A diagram. The line marked by TH/CA represents the boundary between tholeiitic and calc-alkaline rocks (after Irvine and Barager, 1971; Stow and others, 1984).

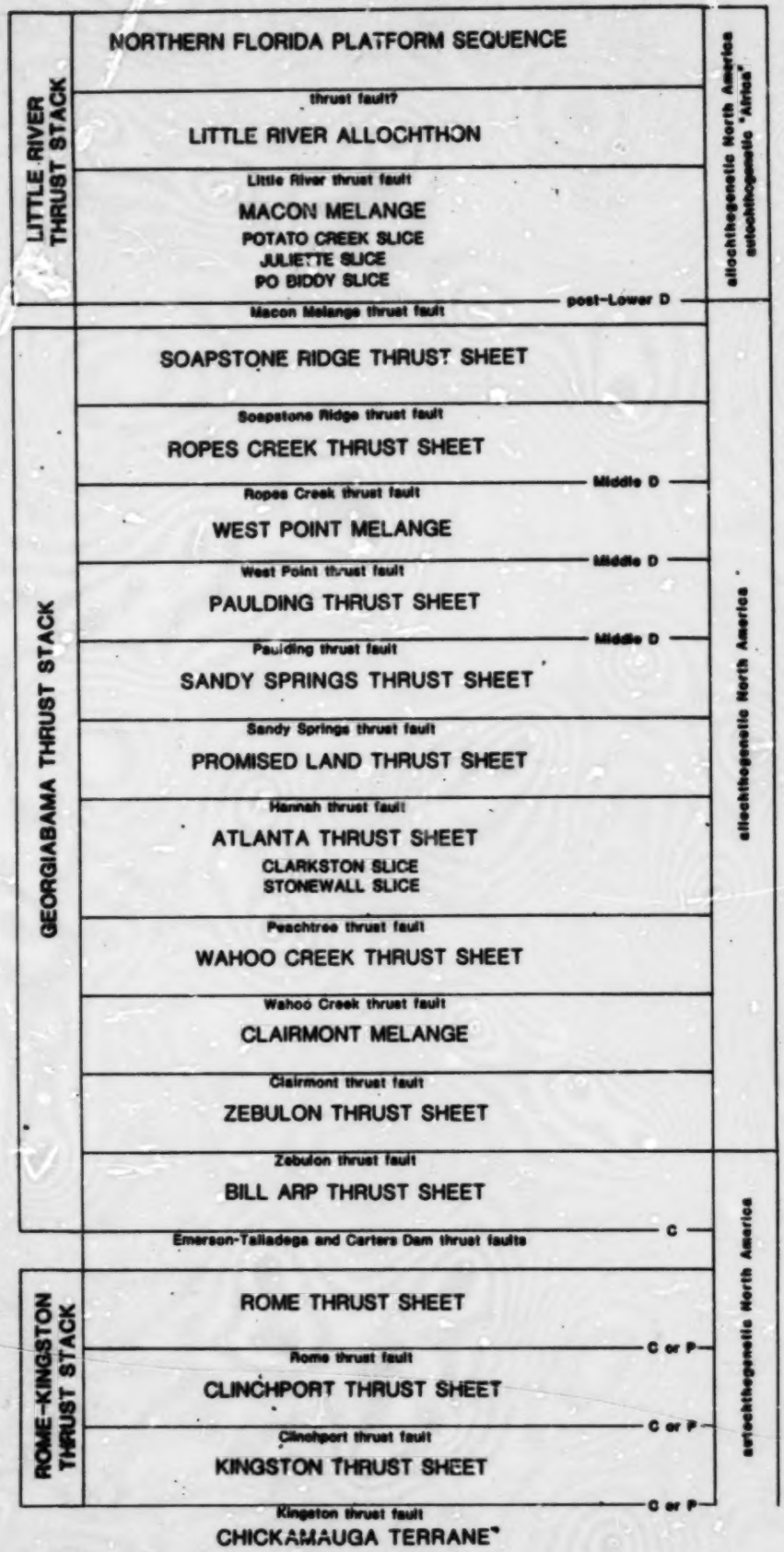


FIGURE 2. Thrust sheets and stacking order.

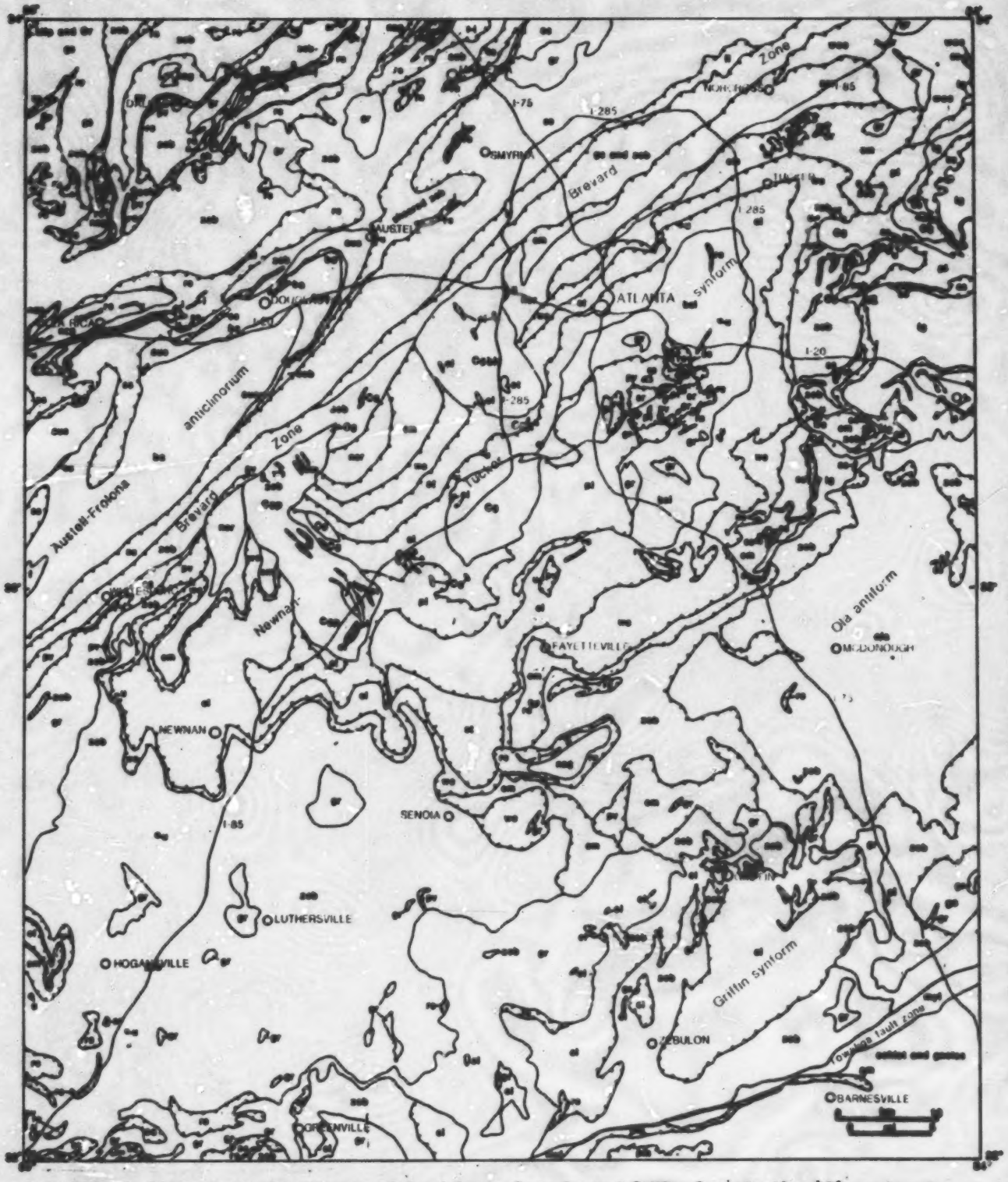


FIGURE 3. Generalized geologic map of the Atlanta, Georgia, and Griffin, Georgia 1° x 30' quadrangles.

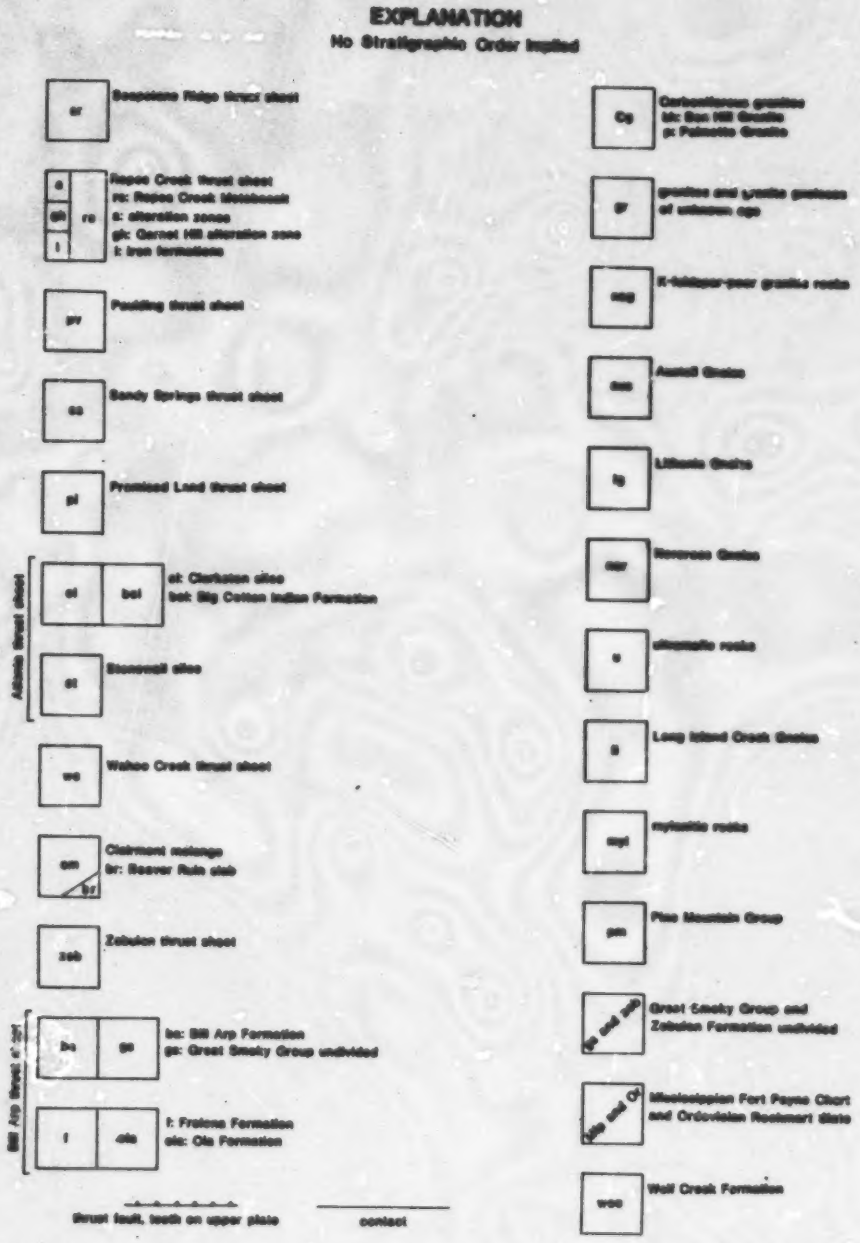


FIGURE 3 (cont.)

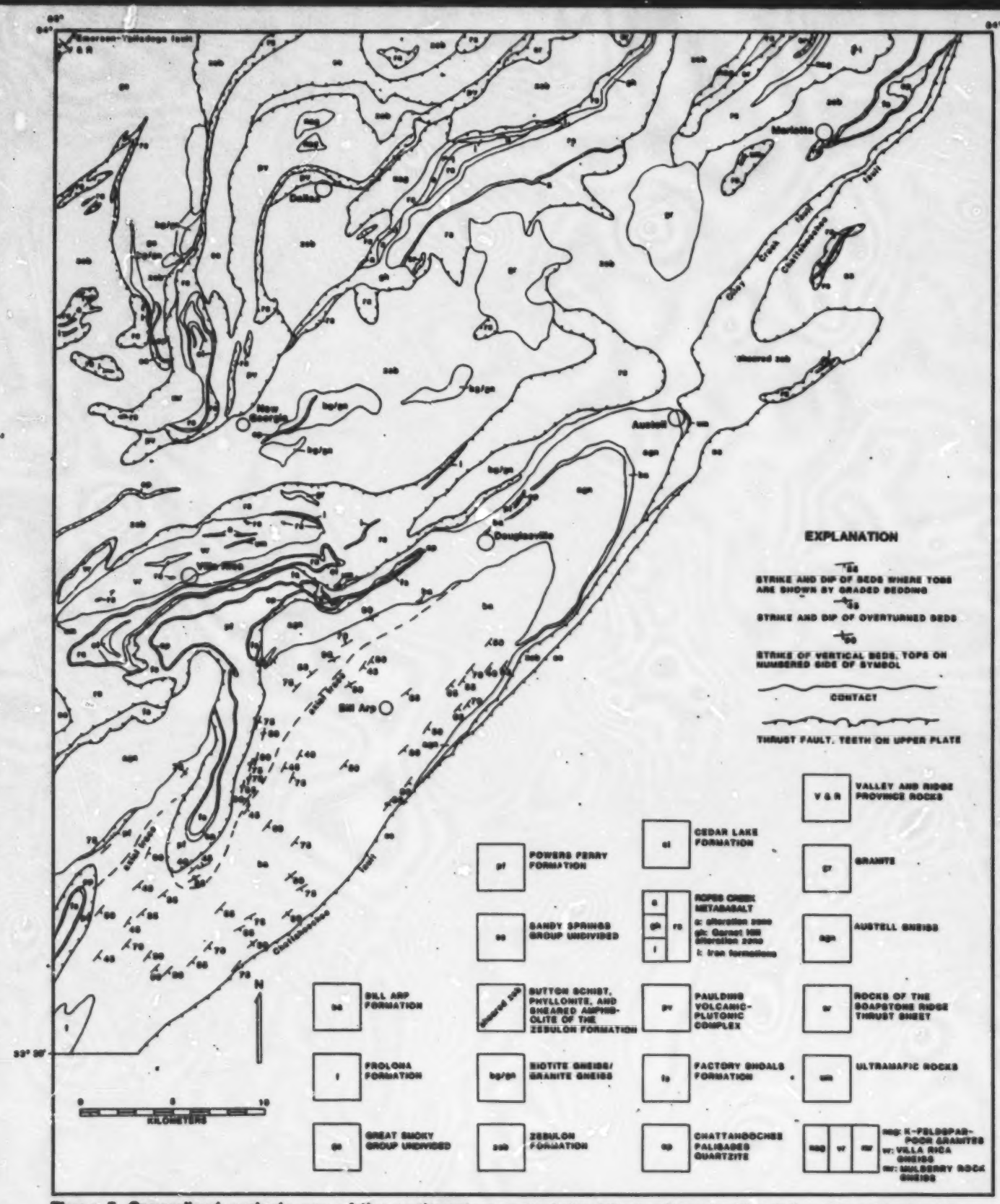


Figure 5. Generalized geologic map of the northwestern part of the Atlanta, Georgia 1° x 30' quadrangle showing attitudes and facing of graded beds in the Bill Arp Formation in the Austell–Frolona anticlinorium. Each symbol represents locality where four or more graded beds give facing direction. Dips are averaged and rounded. See text for futher explanation.

FIGURE 6A

FIGURE 6B

FIGURE 6L

FIGURE 6D

FIGURE 6 E

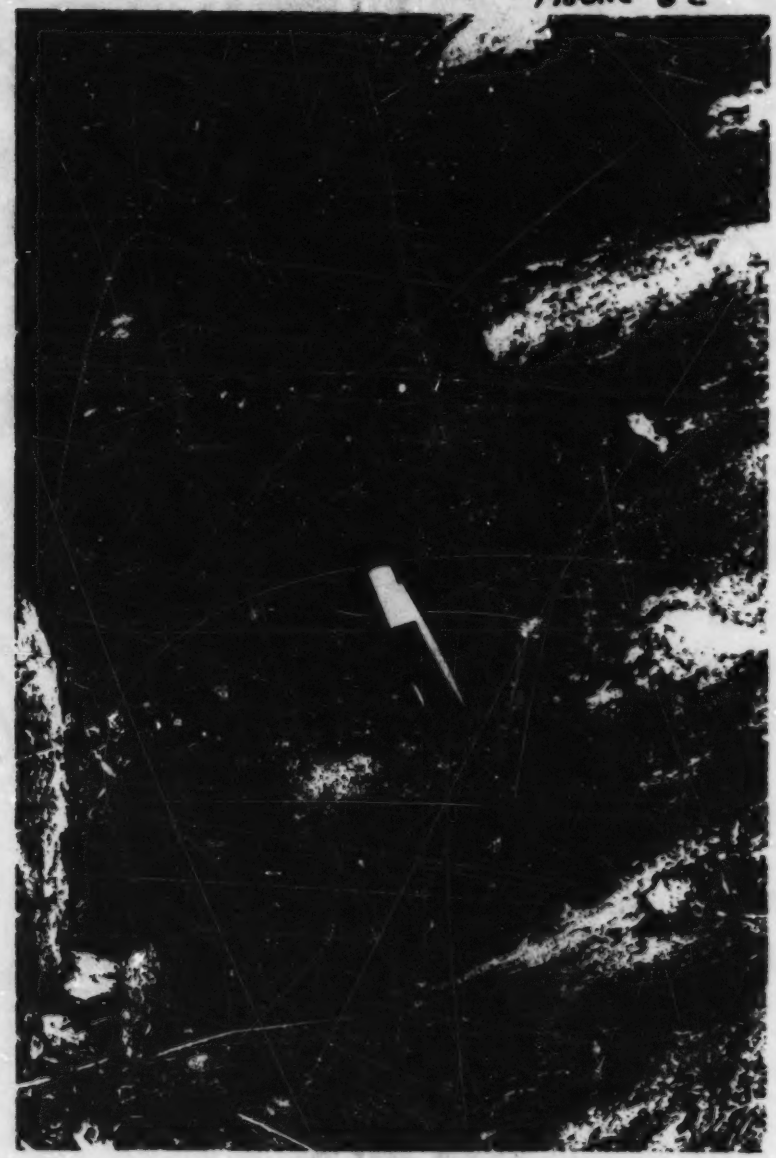


FIGURE 7A

FIGURE 7B

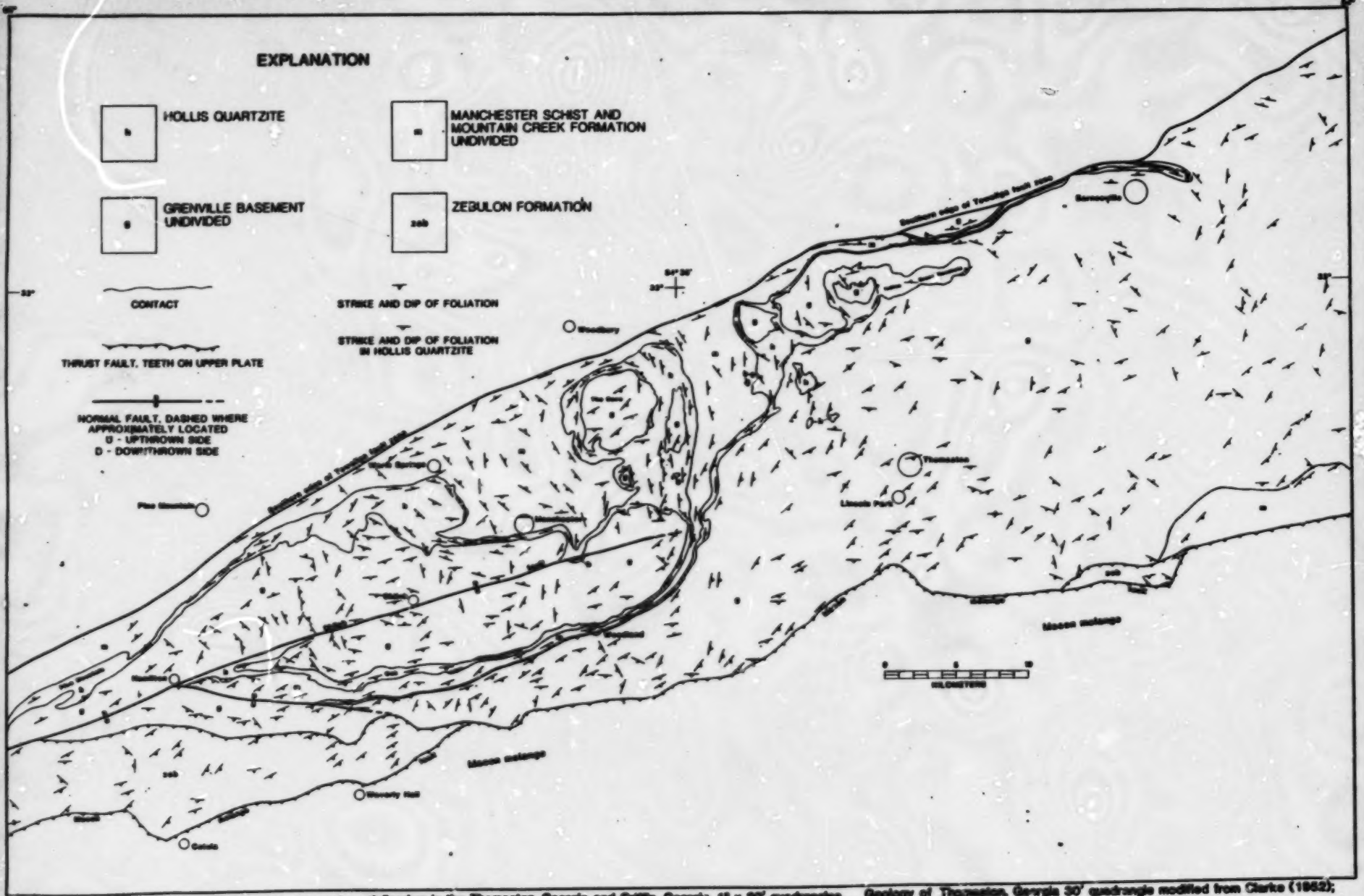


Figure 6. Generalized geologic map of the Pine Mountain anticlinorium in the Thomaston, Georgia and Griffin, Georgia 1° x 30' quadrangles. Geology of Thomaston, Georgia 30' quadrangle modified from Clarke (1962); Warm Springs, Georgia 30' quadrangle modified from Hewett and Crickmay (1937).

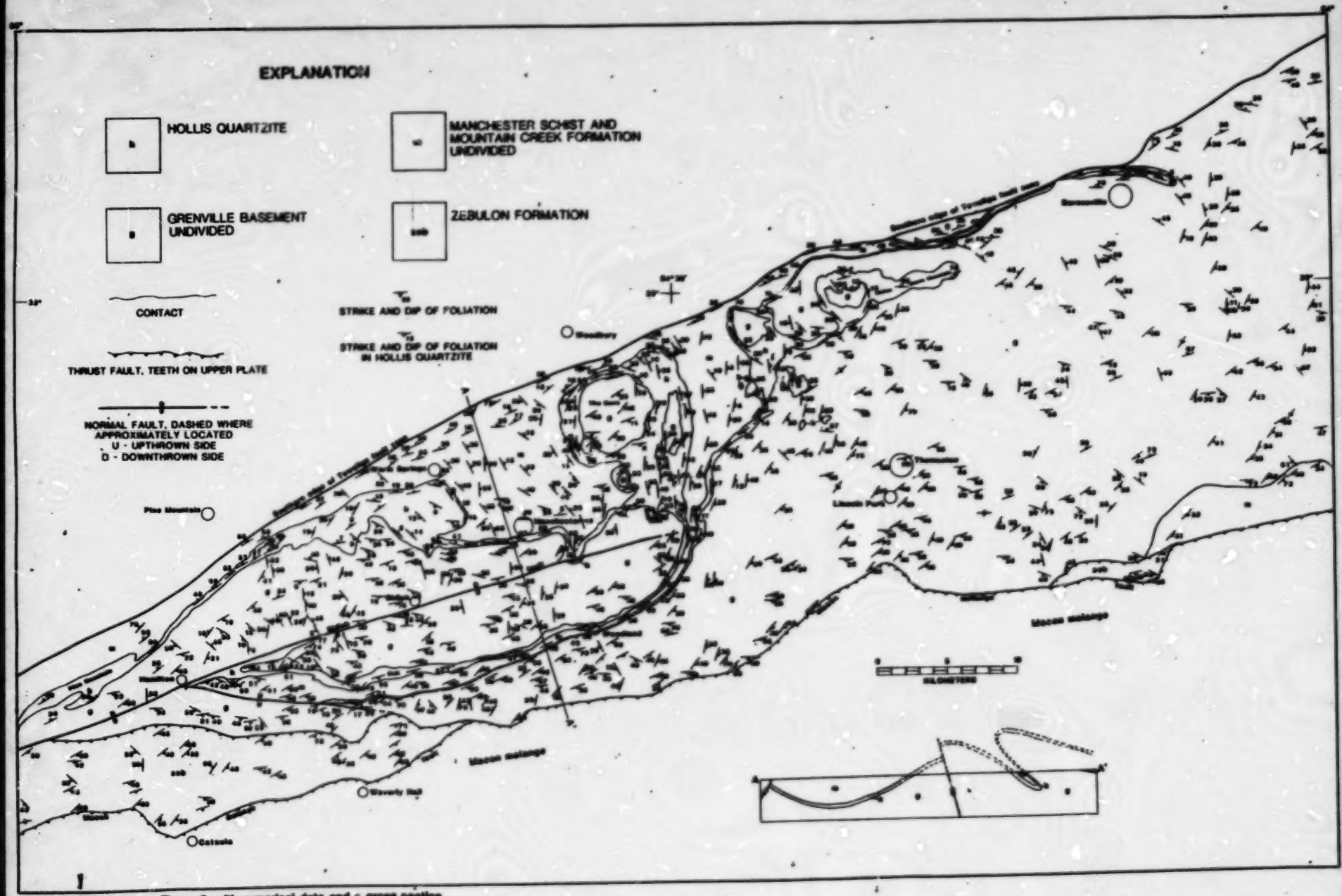


Figure 9. Same map as Figure 8, with numerical data and a cross section.

FIGURE 10

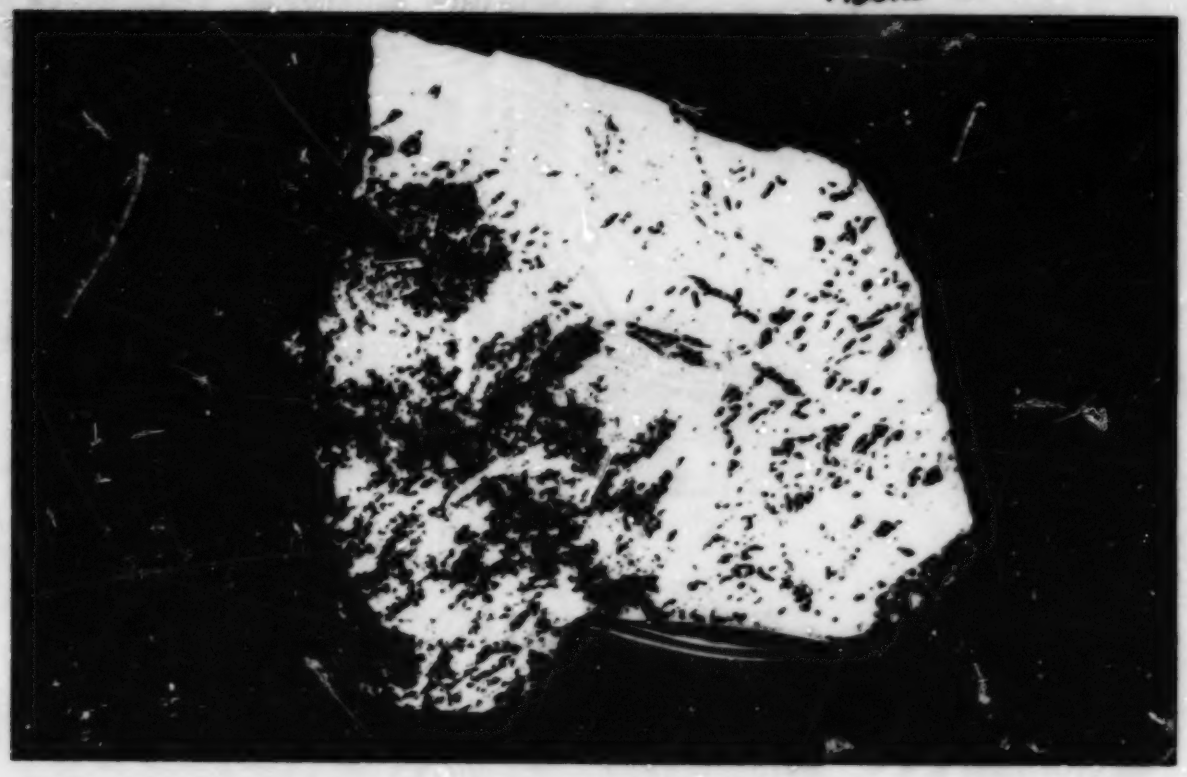


FIGURE 11

FIGURE 12

FIGURE 14

FIGURE 4A

FIGURE 4B

FIGURE 16C

FIGURE 16D

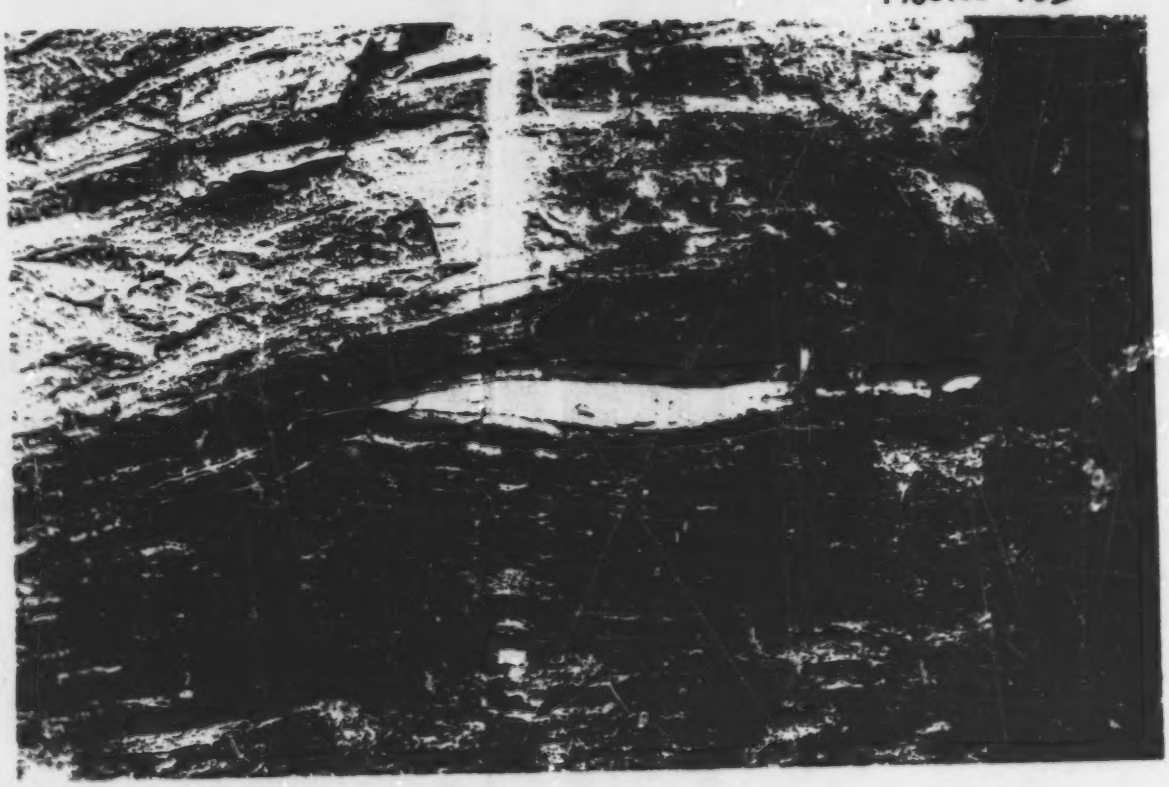


FIGURE 17A

FIGURE 17B

FIGURE 18A

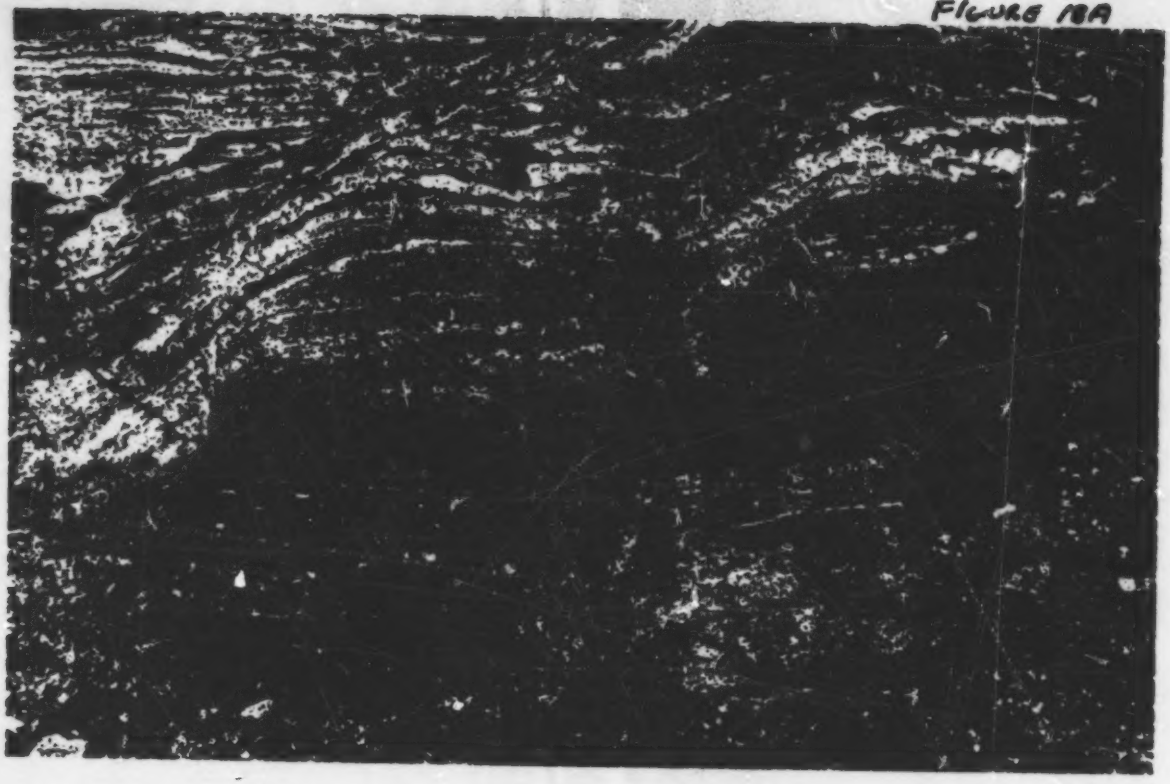


FIGURE 18B

FIGURE 18C

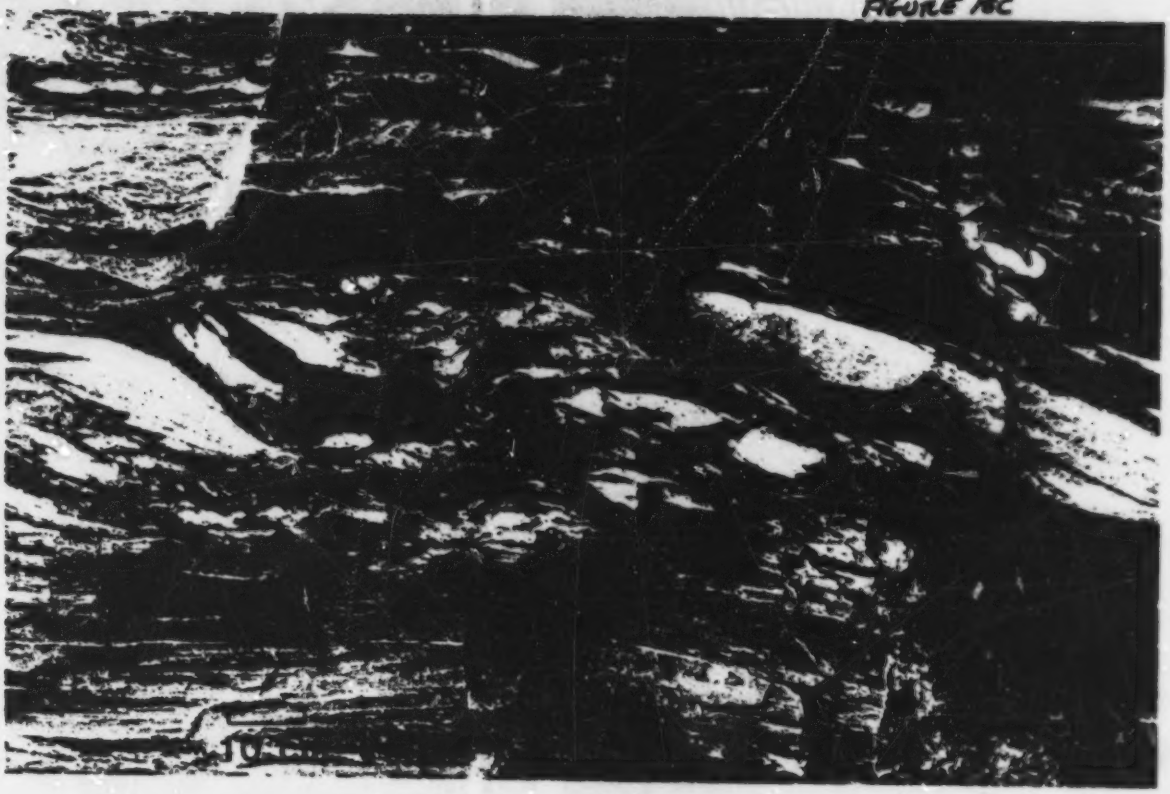


FIGURE 18D

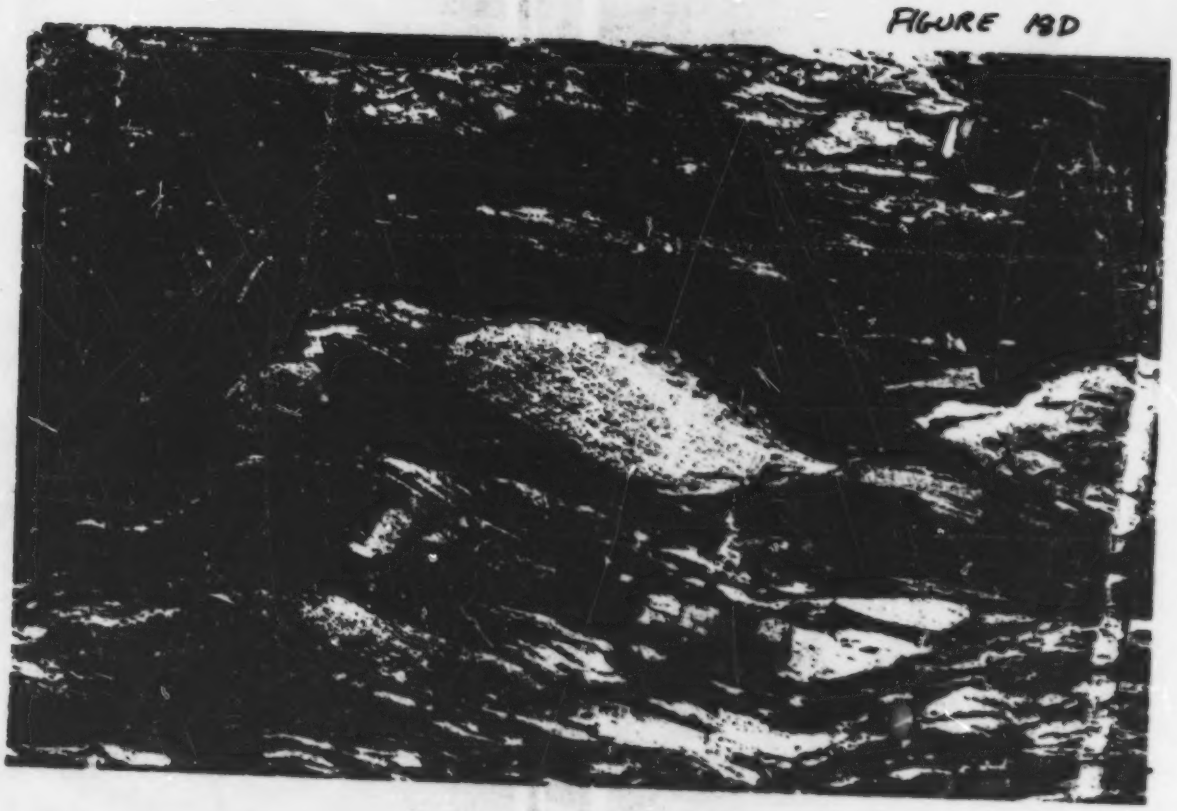


FIGURE 20A

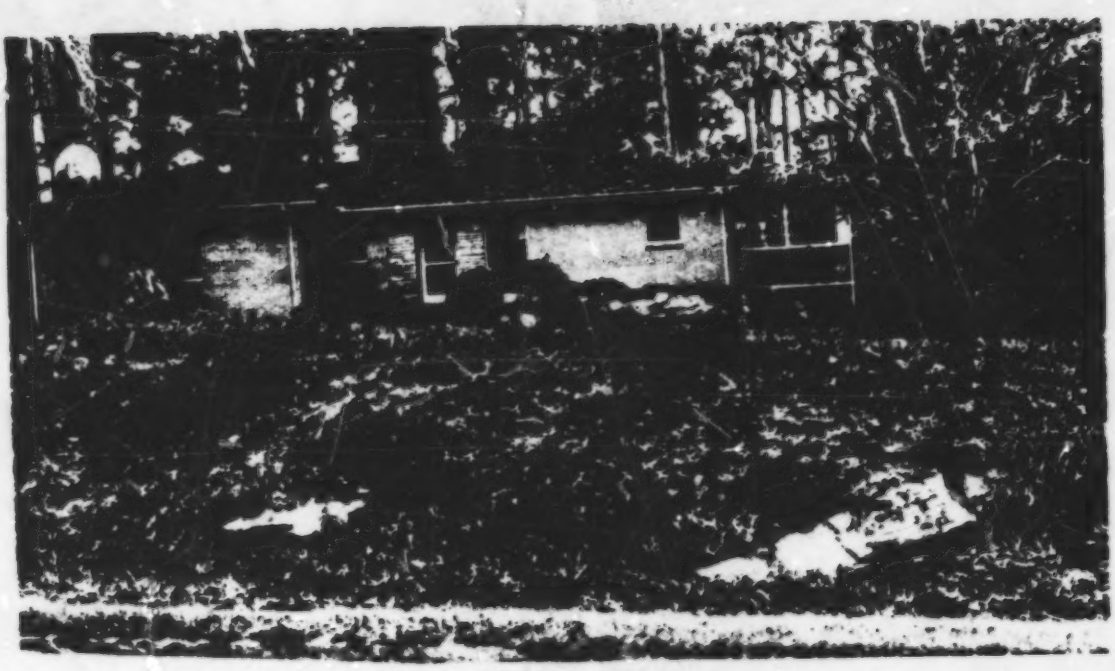


FIGURE 20B

FIGURE 21

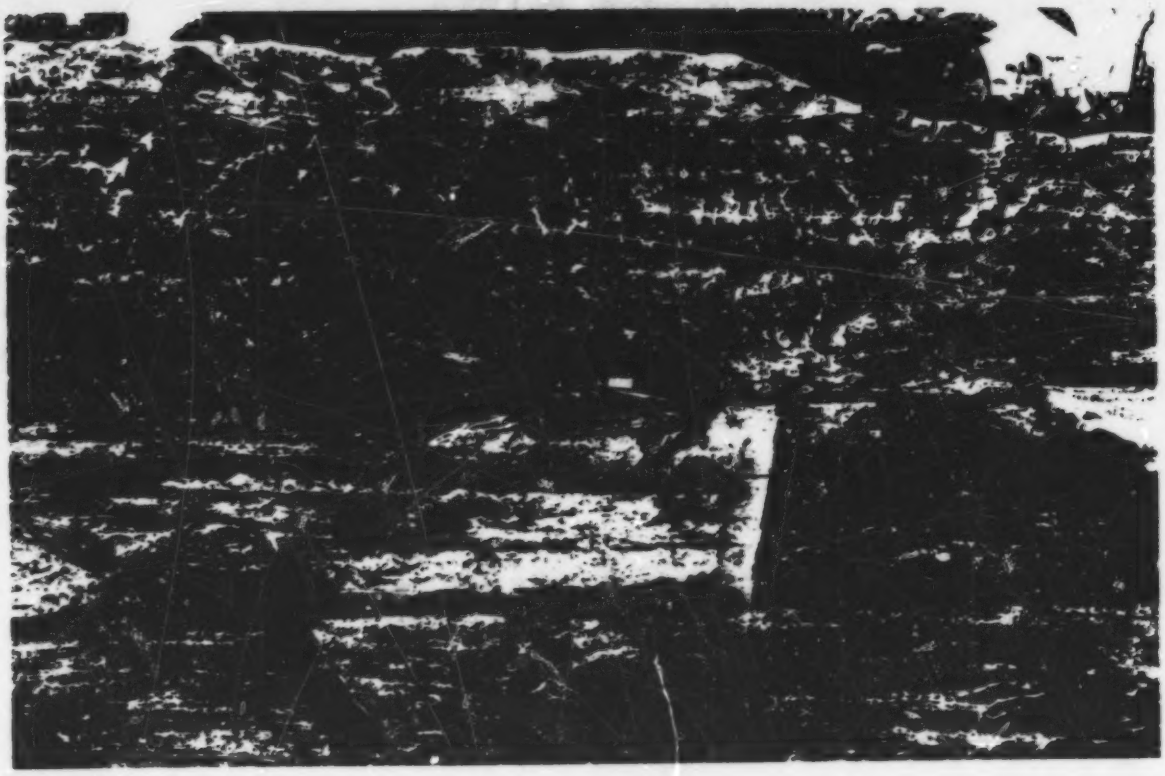


FIGURE 23A

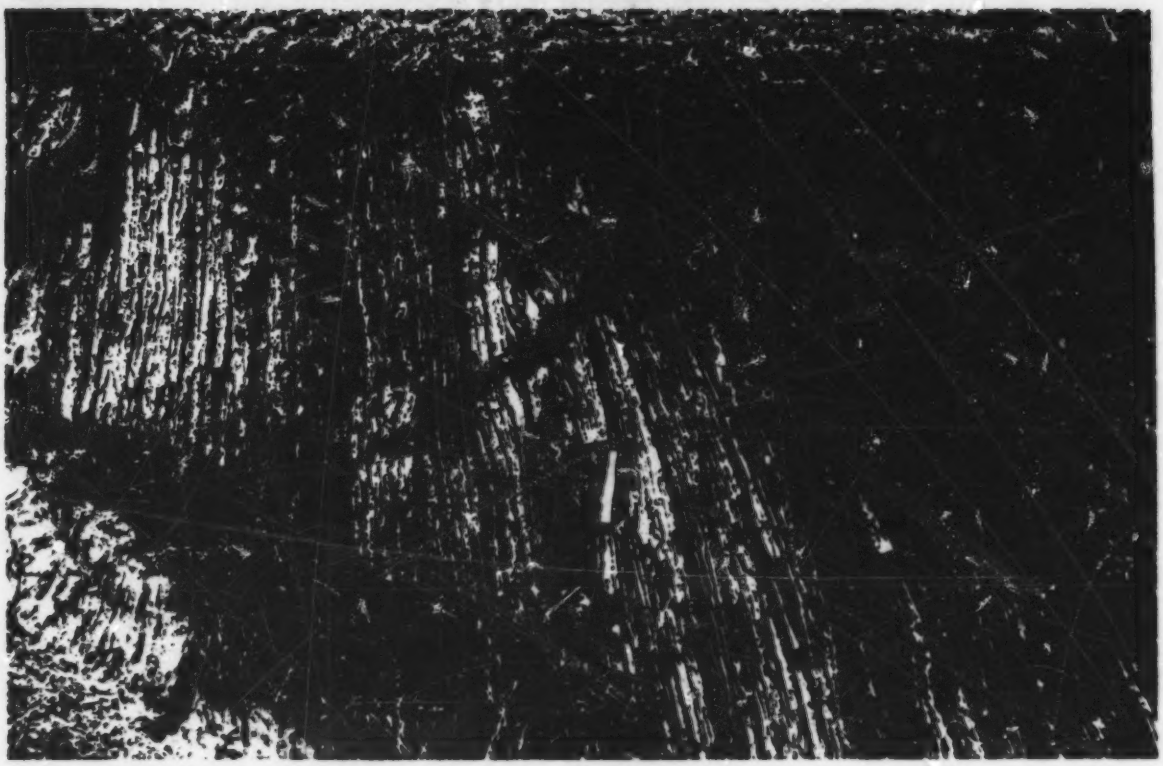


FIGURE 23B

FIGURE 24A

FIGURE 24B

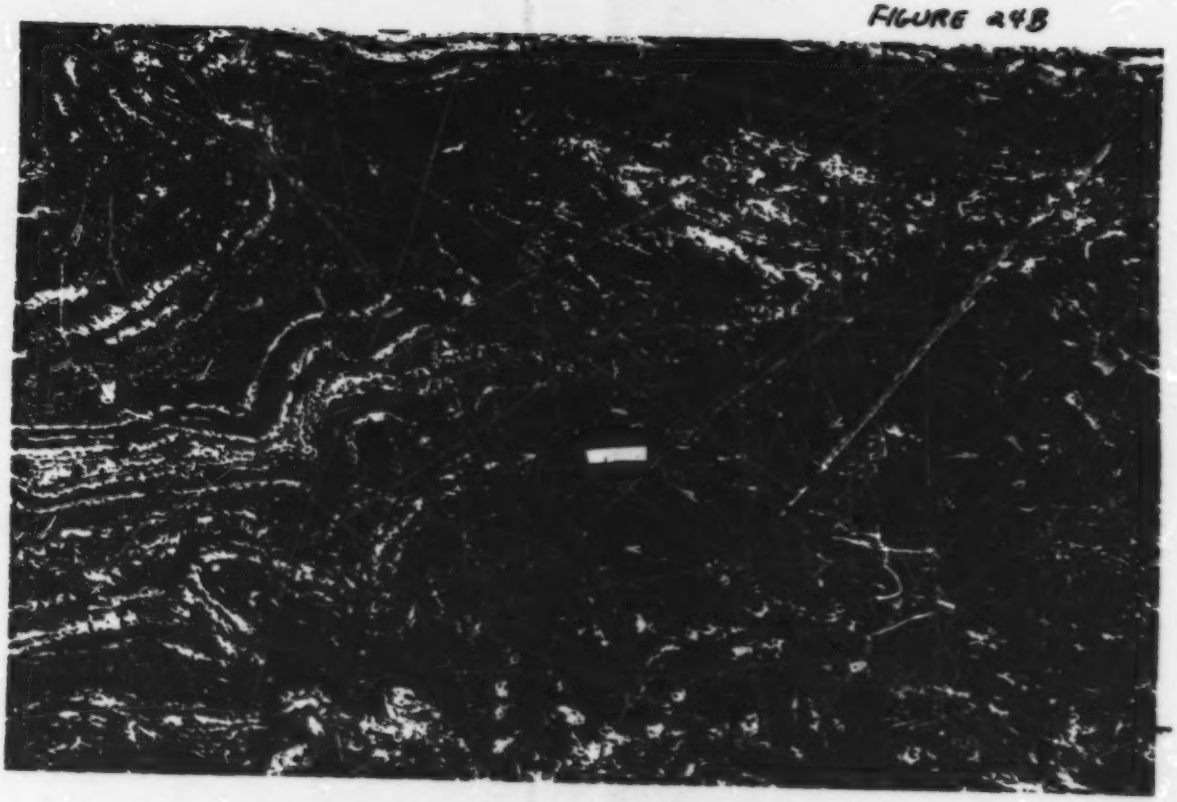


FIGURE 24C

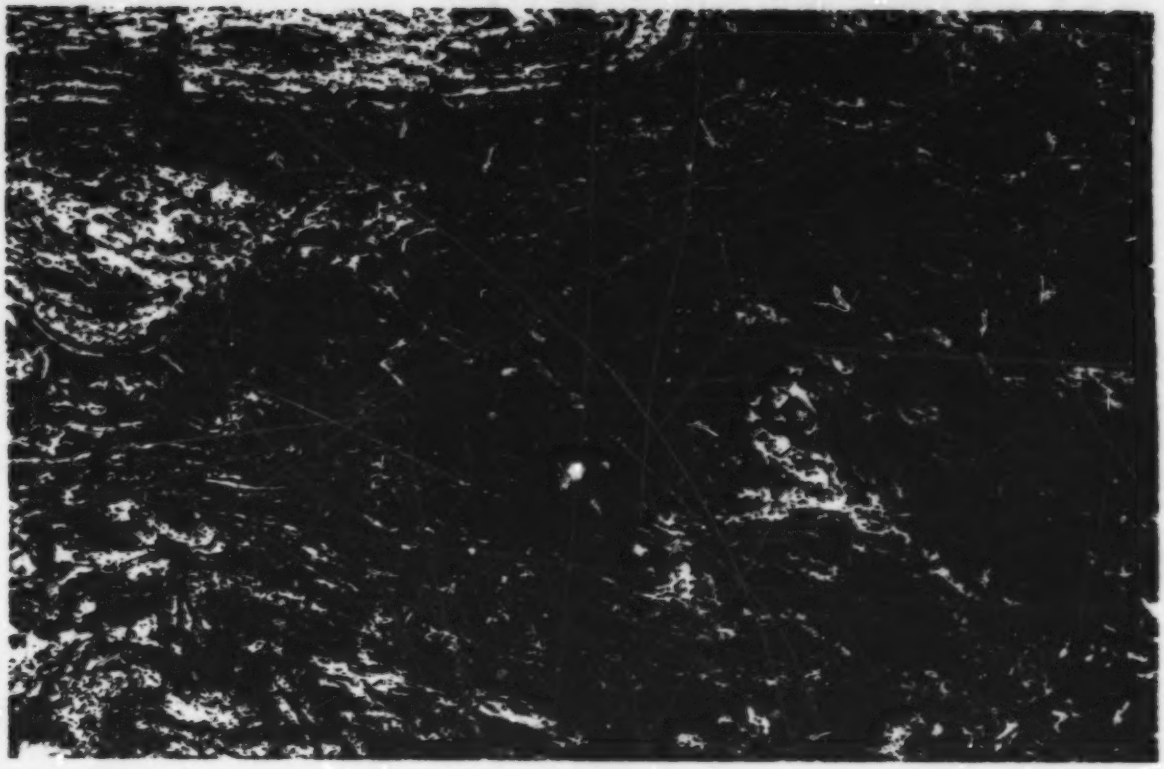


FIGURE 26

FIGURE 28A

FIGURE 28B

FIGURE 28C

FIGURE 30

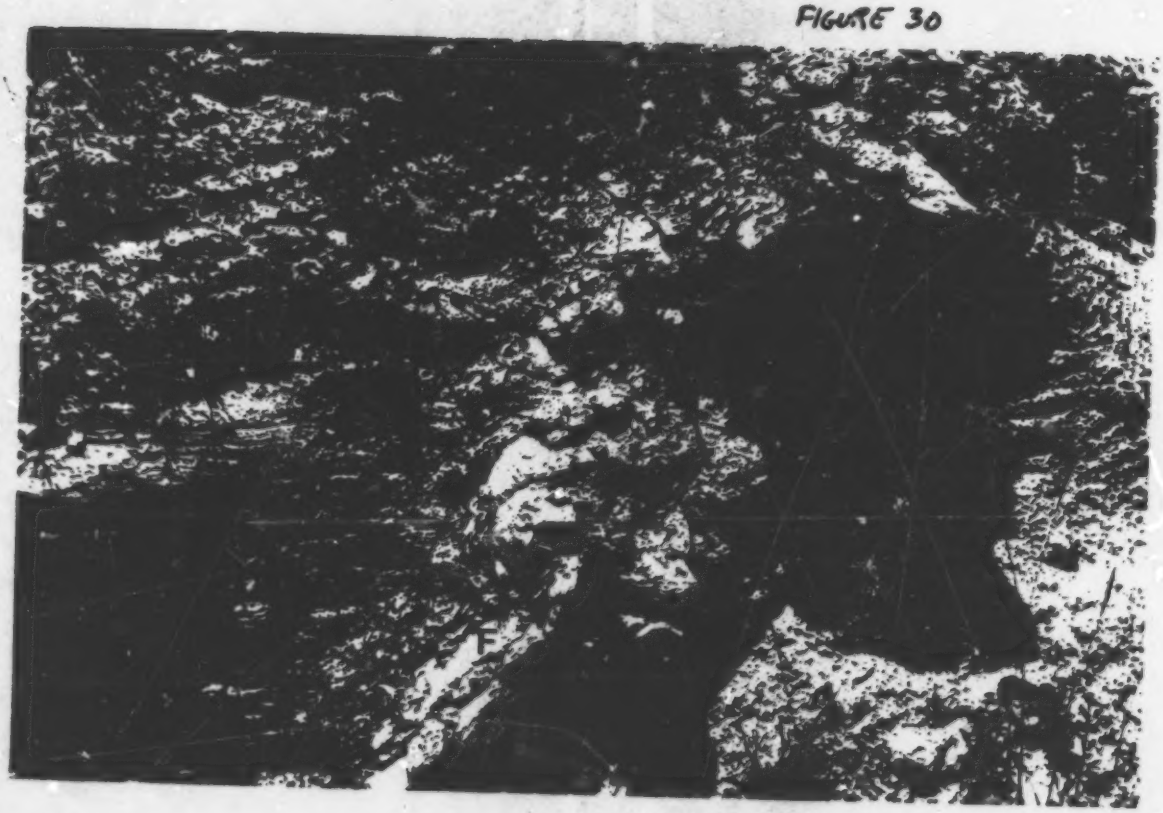


FIGURE 32

FIGURE 33

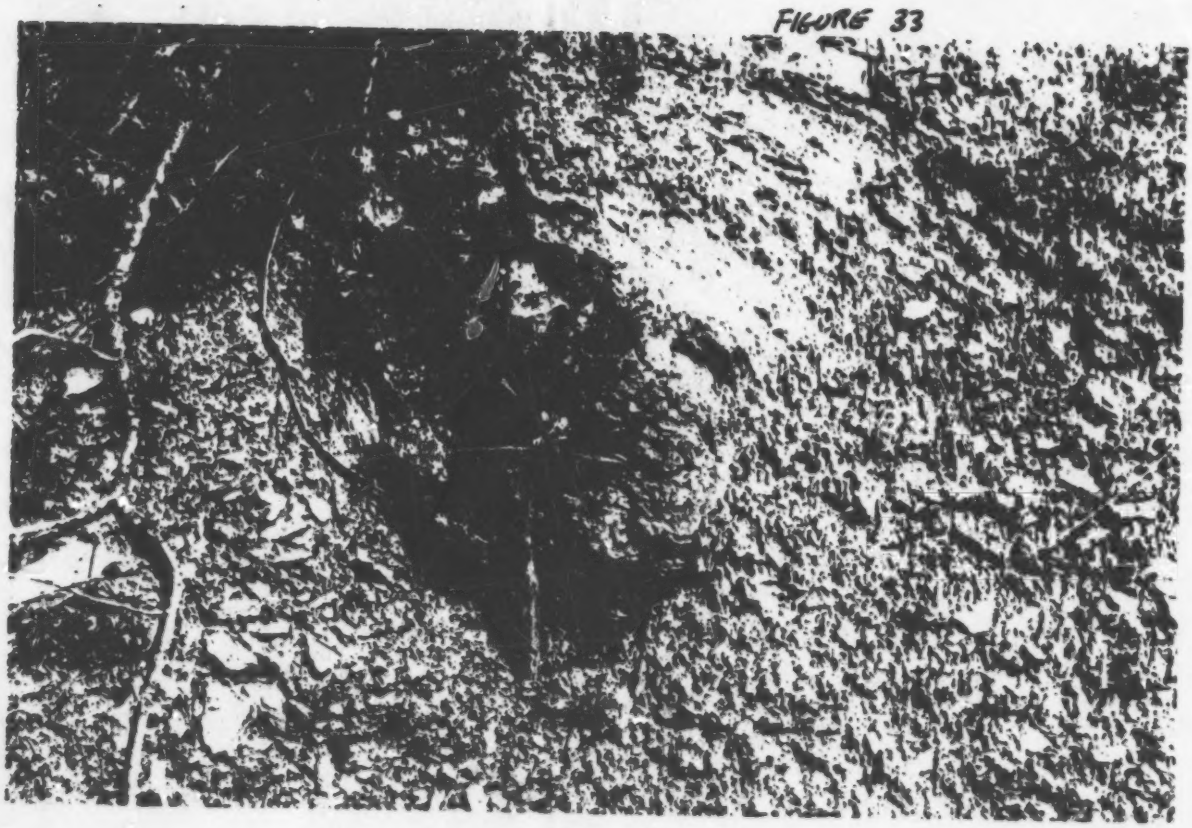


FIGURE 34A

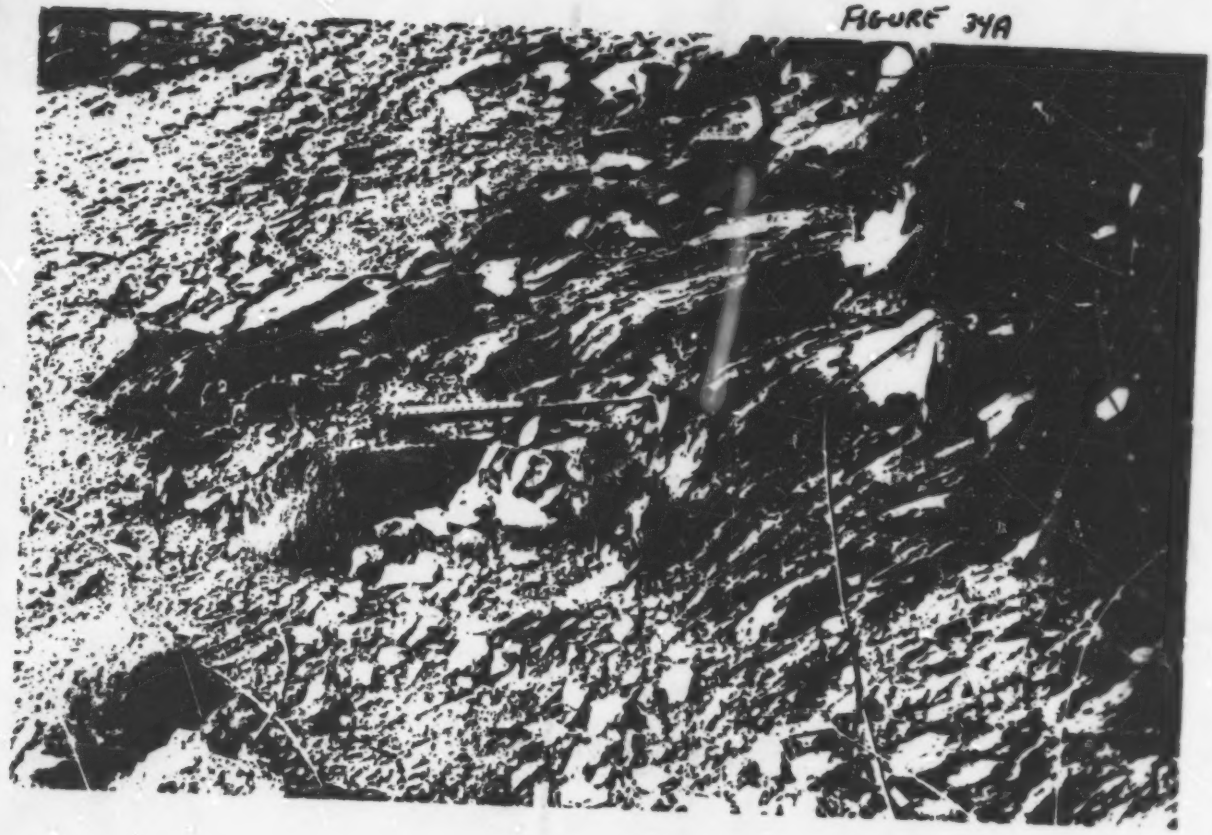


FIGURE 34B

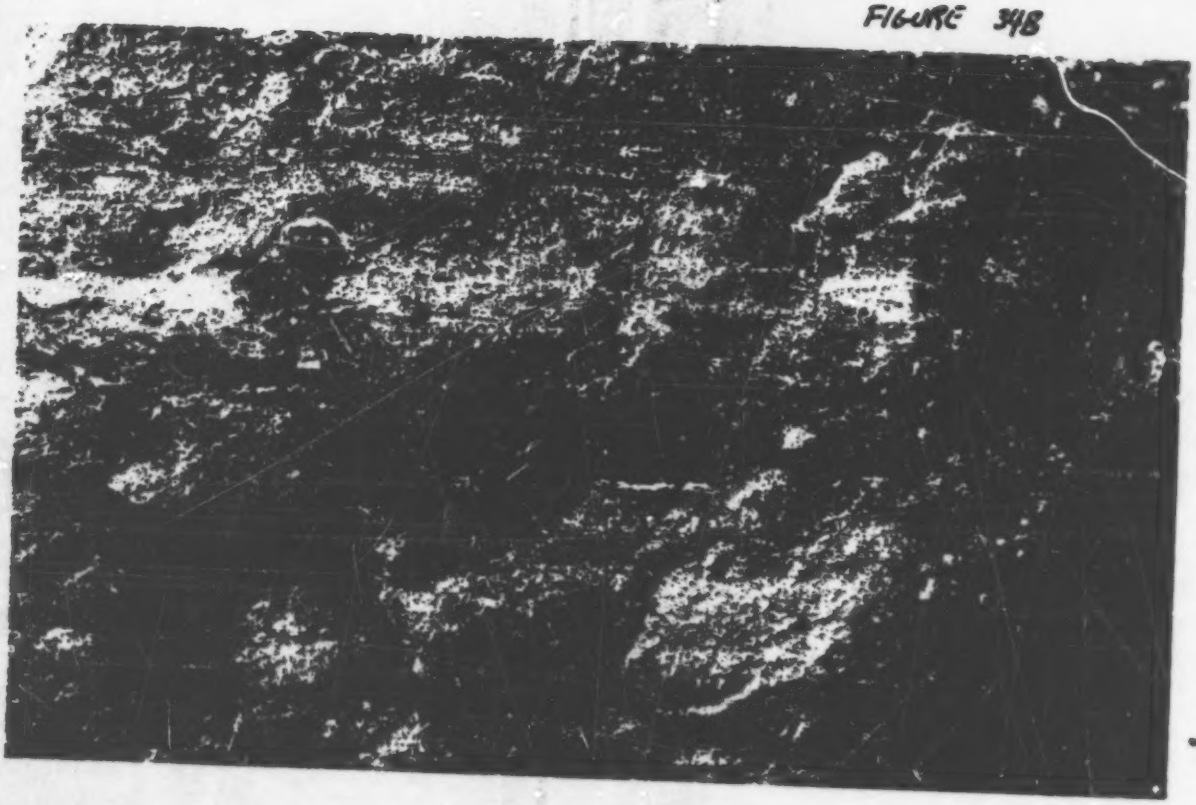


FIGURE 35

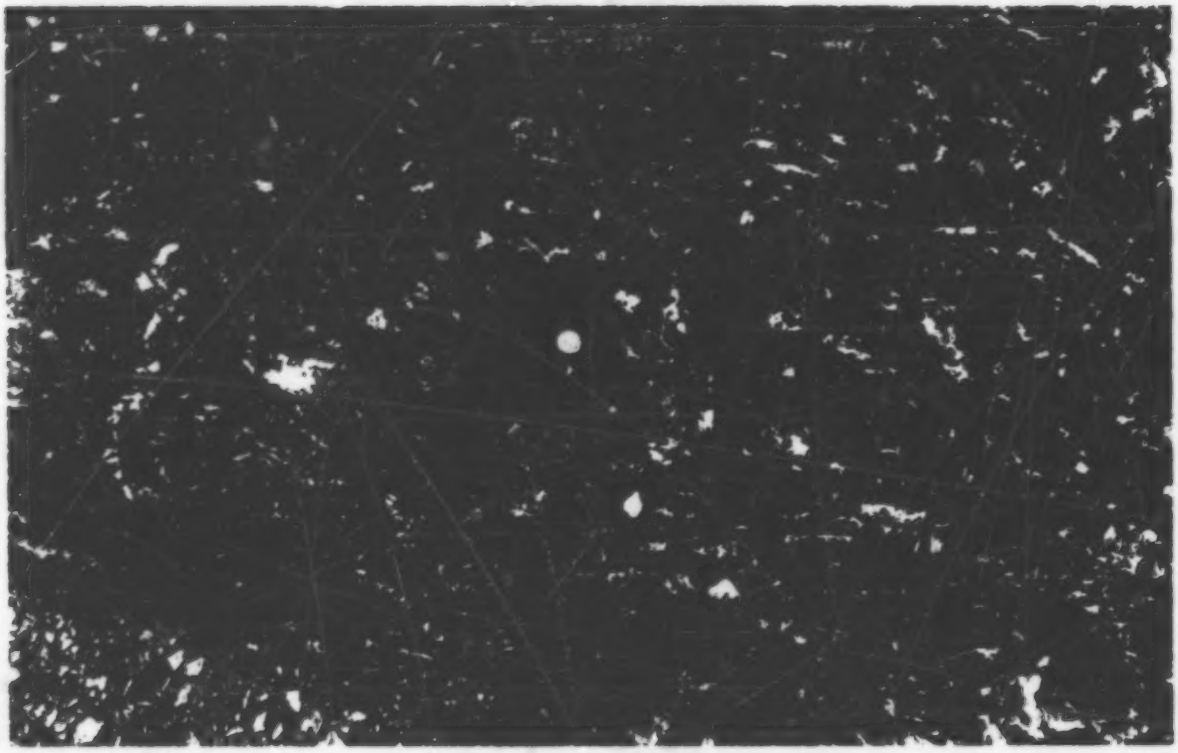


FIGURE 36A

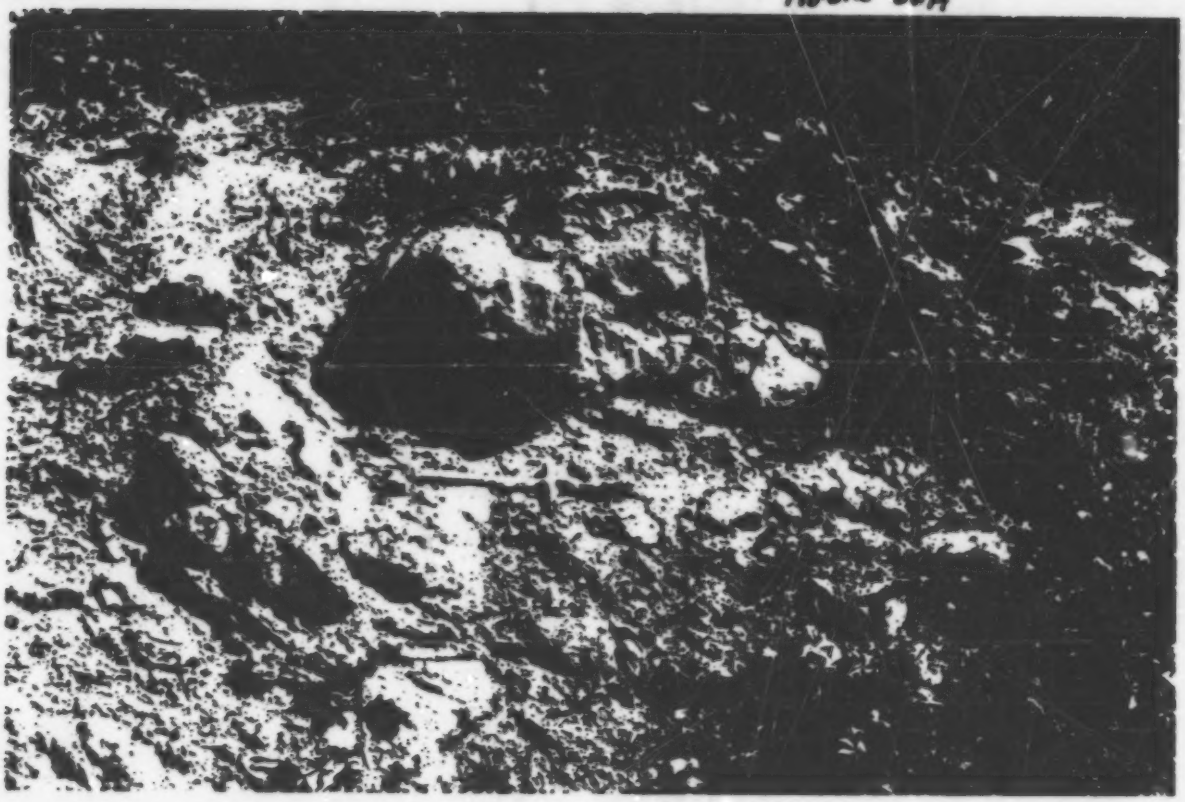


FIGURE 36B

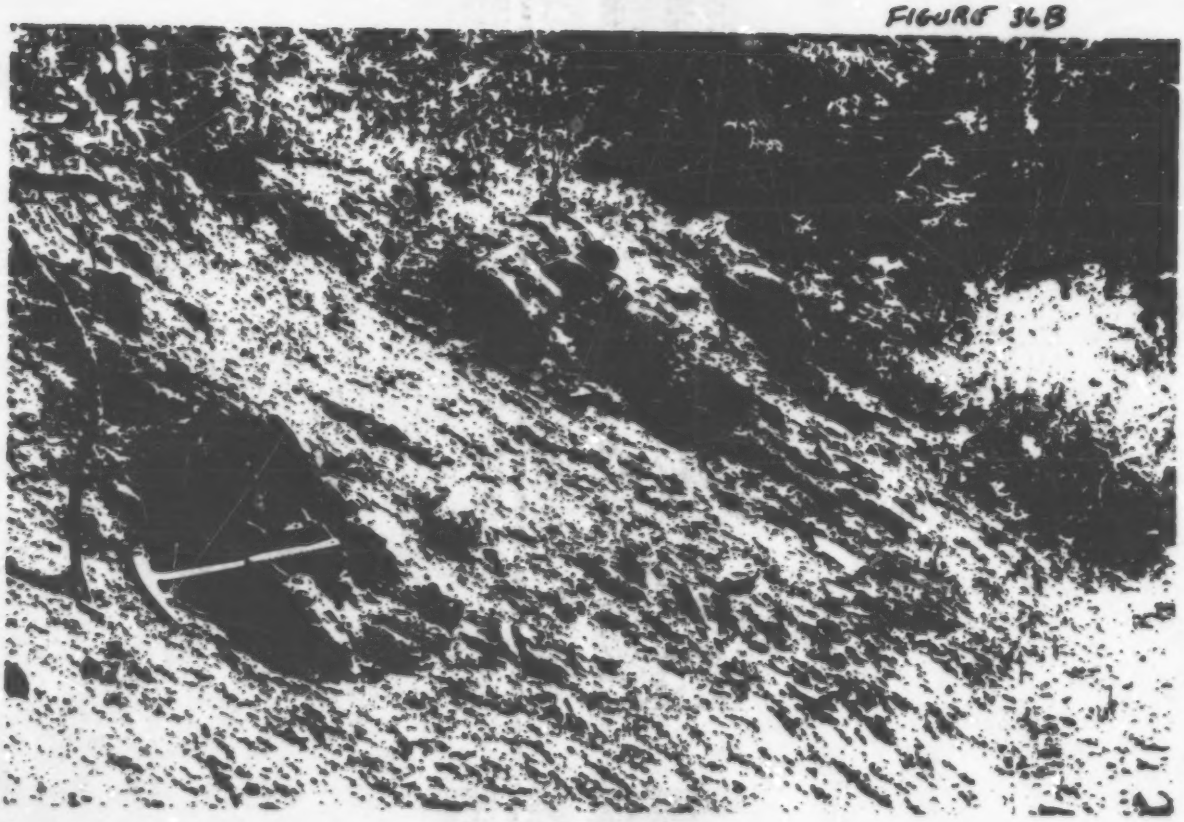


FIGURE 36C

FIGURE 37A

FIGURE 37B

FIGURE 37C

FIGURE 38A

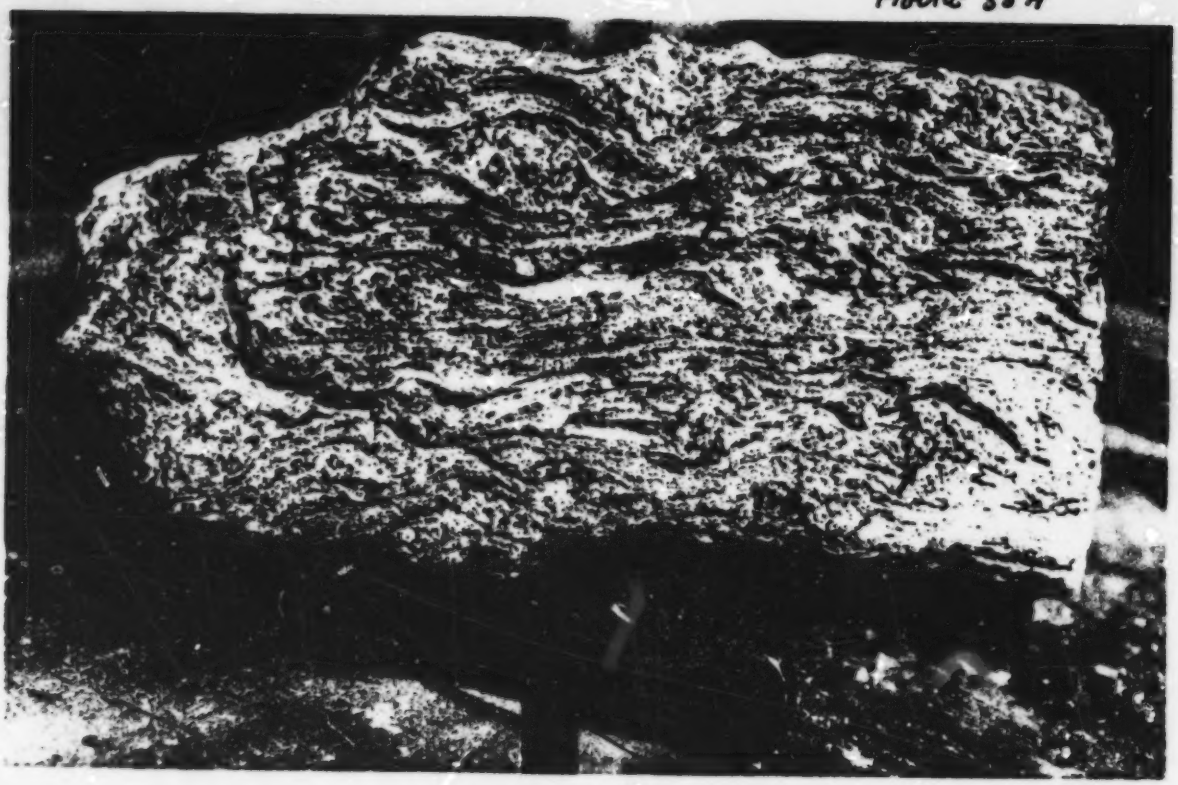


FIGURE 38B

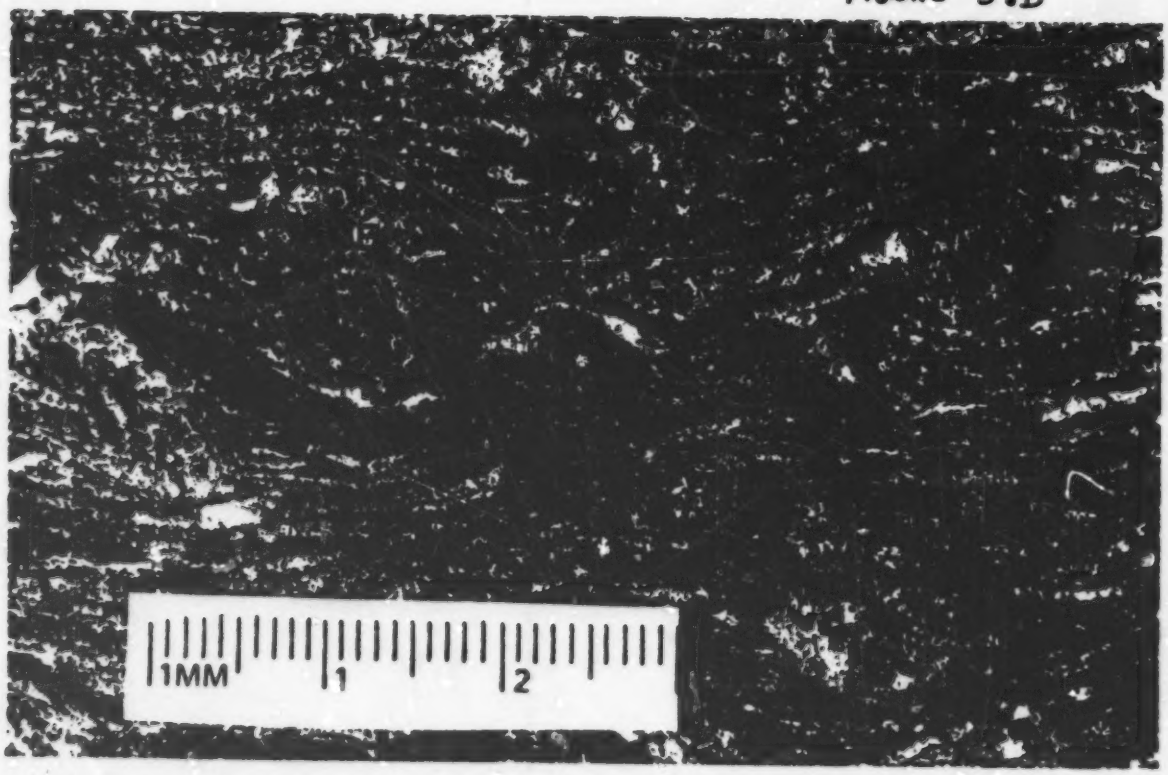


FIGURE 38C

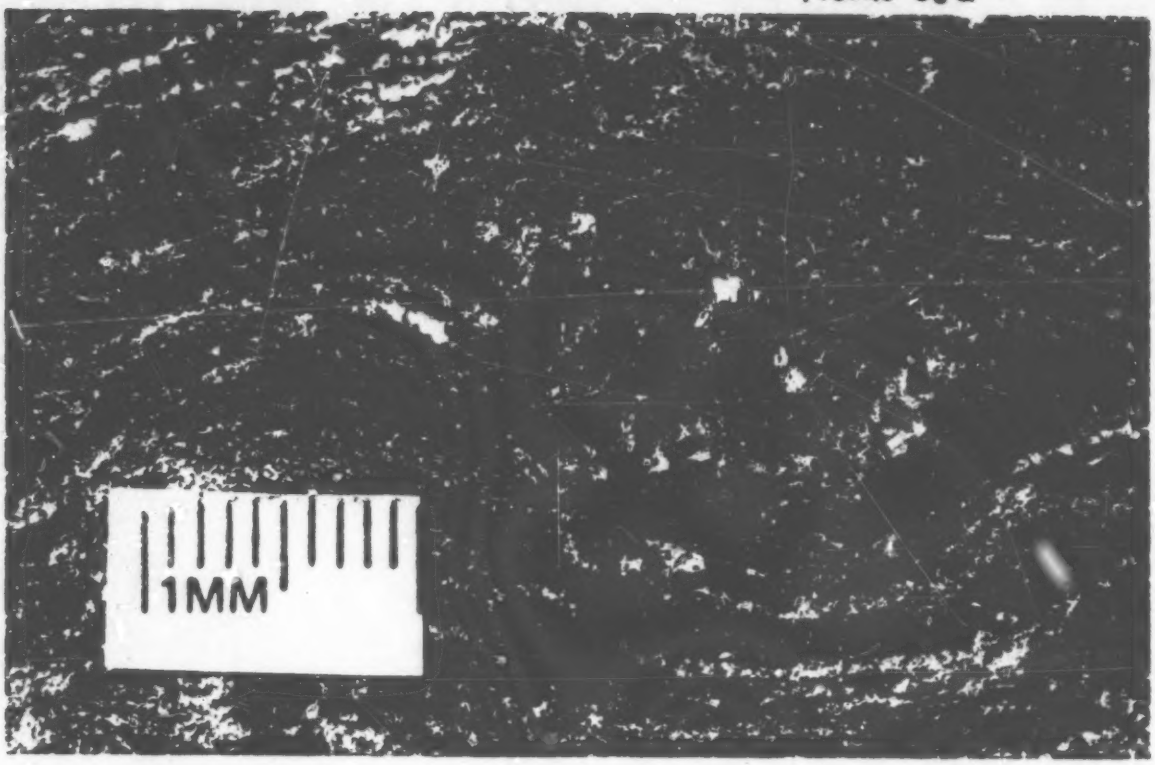


FIGURE 38D

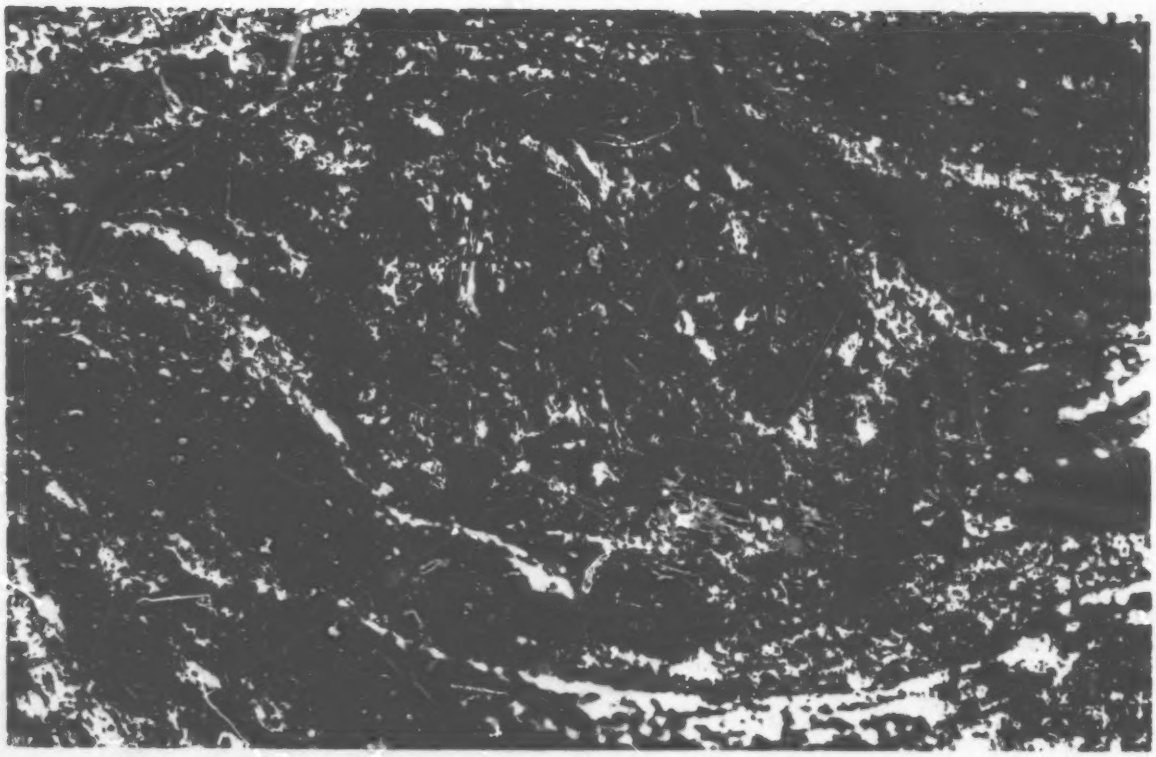


FIGURE 40A

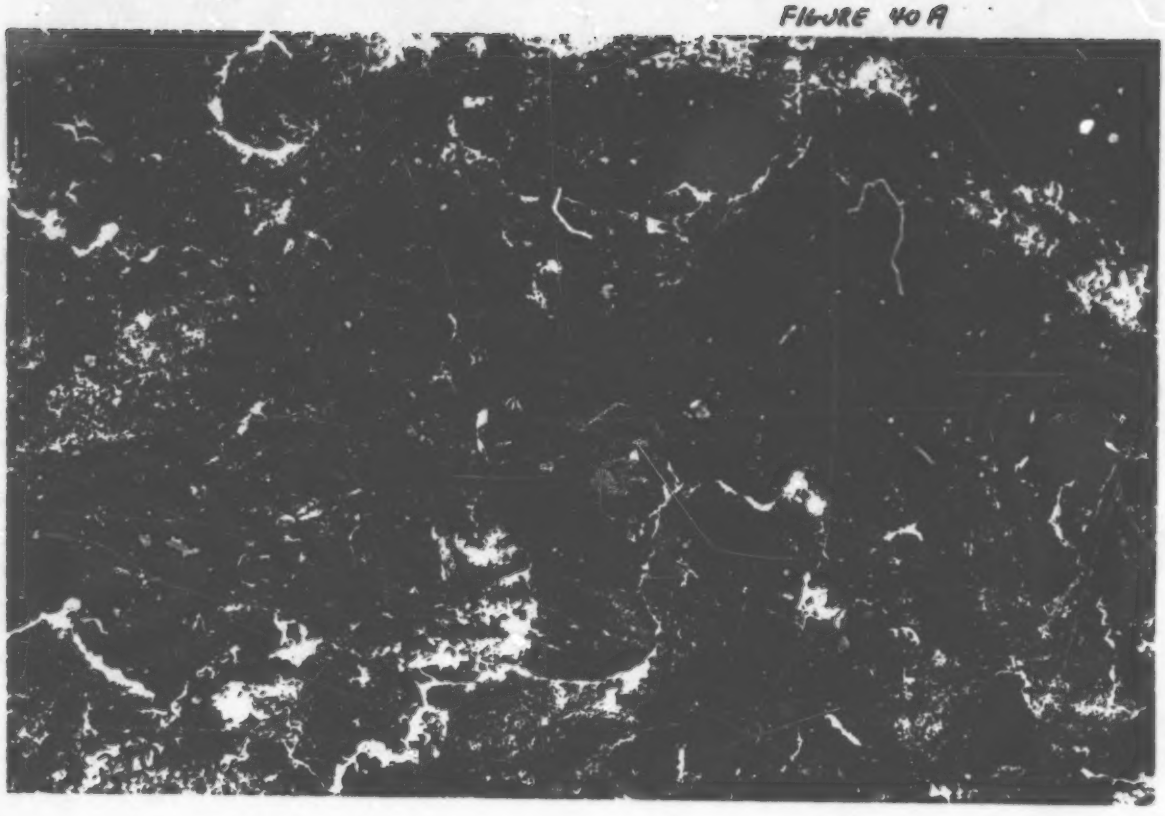


FIGURE 40B

FIGURE 4A

FIGURE 4B

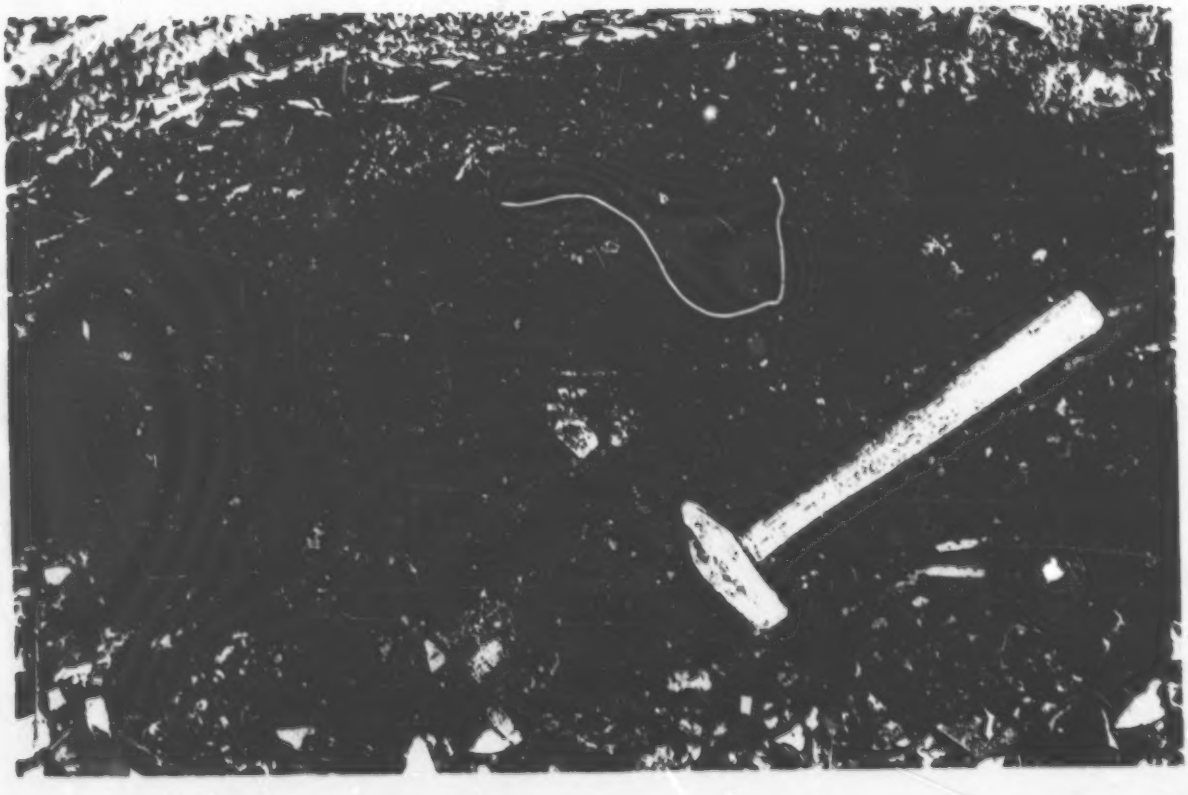


FIGURE 41C

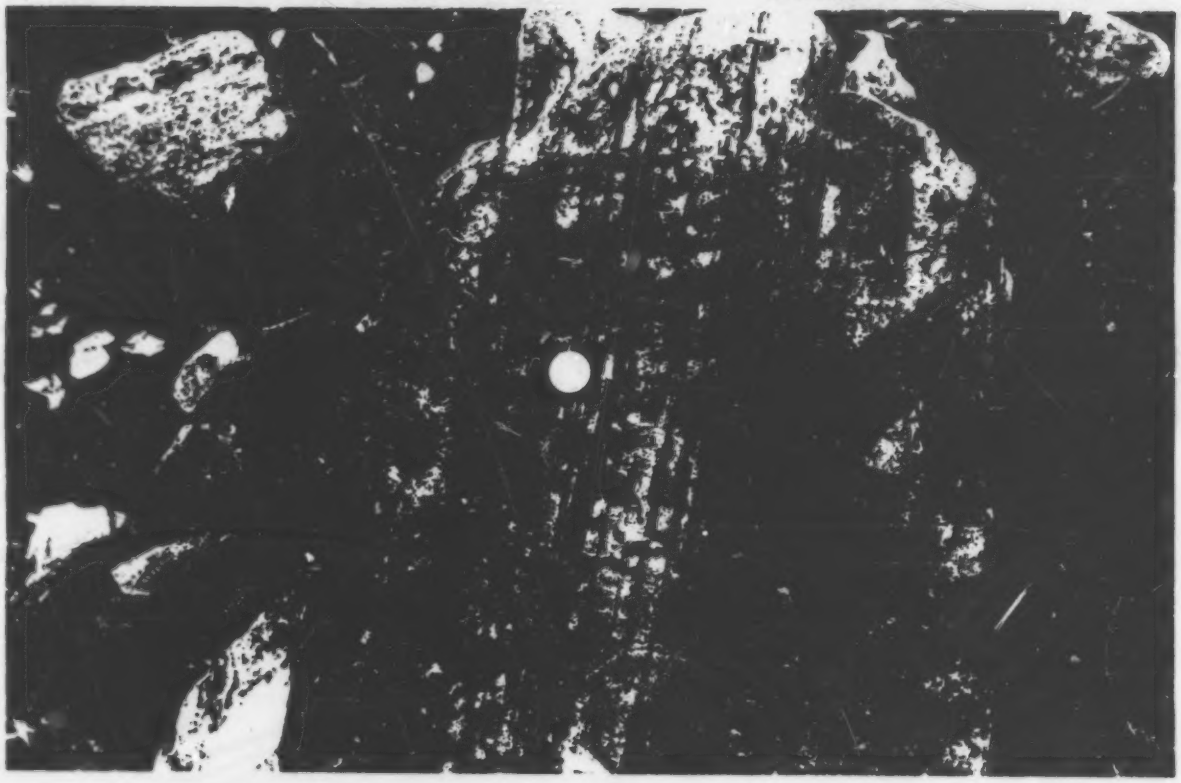


FIGURE 42

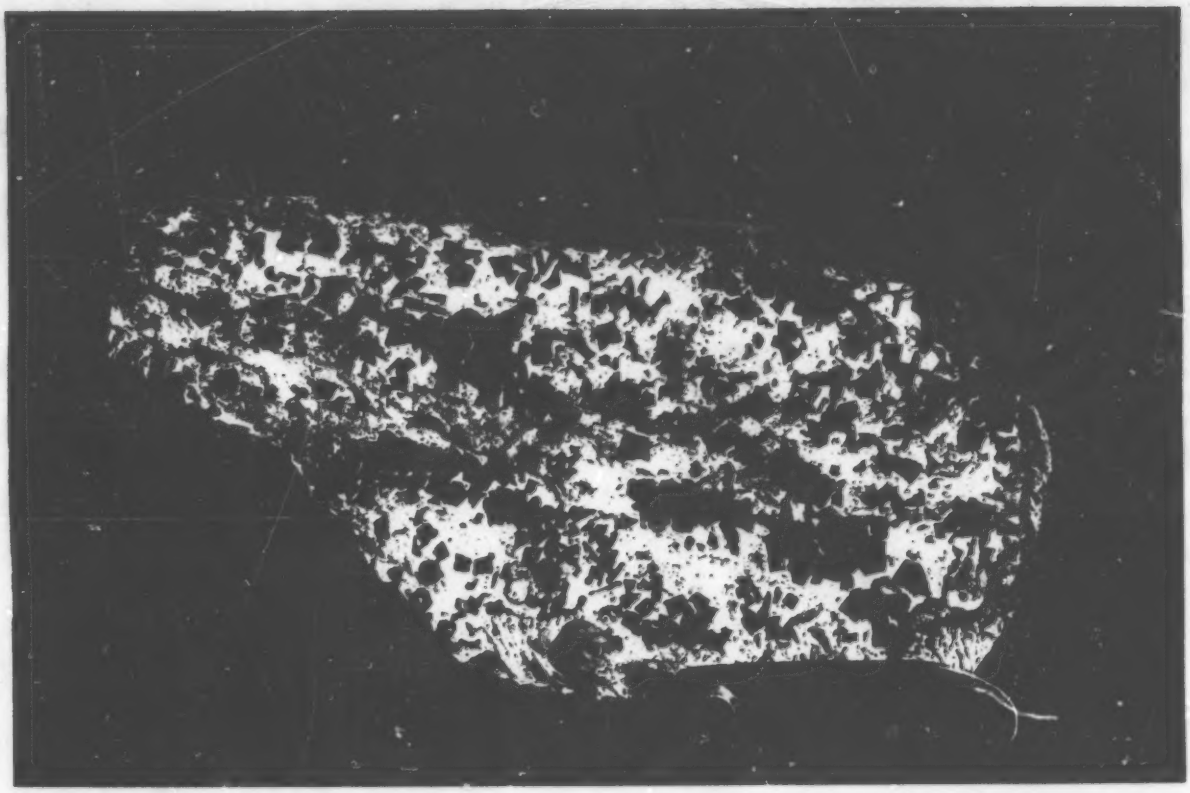


FIGURE 44

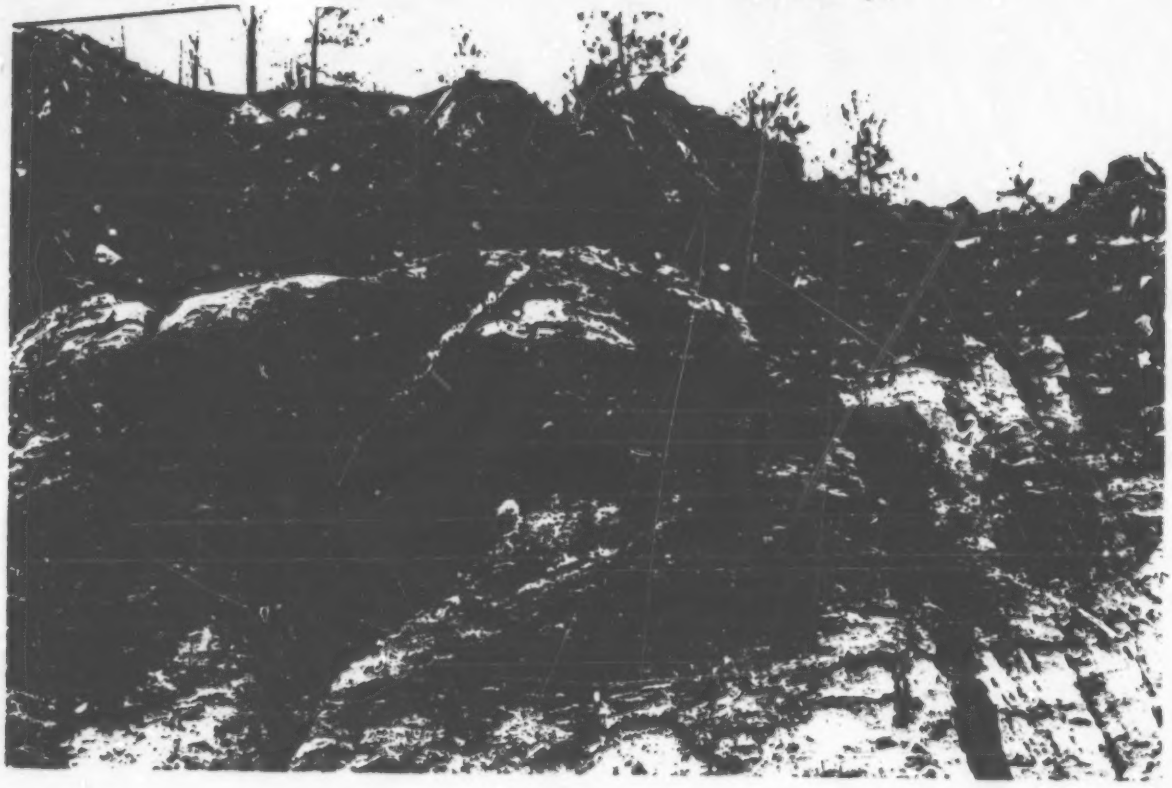


FIGURE 45A

FIGURE 45B

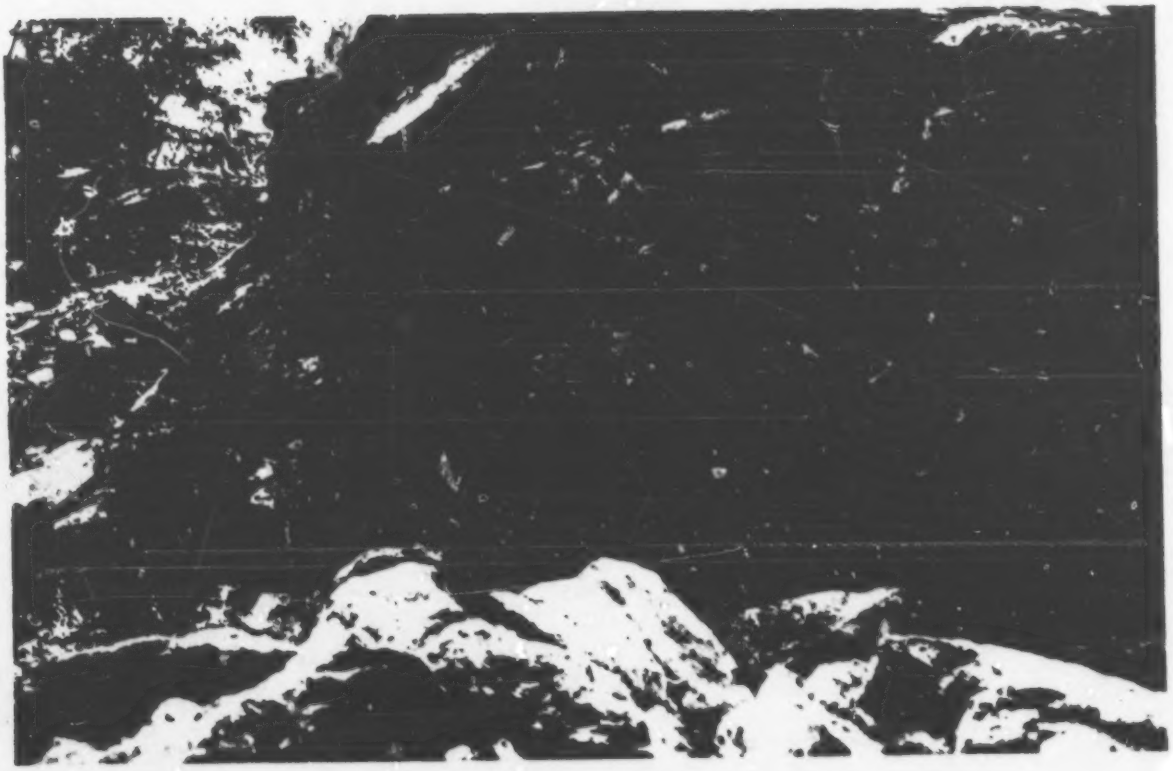
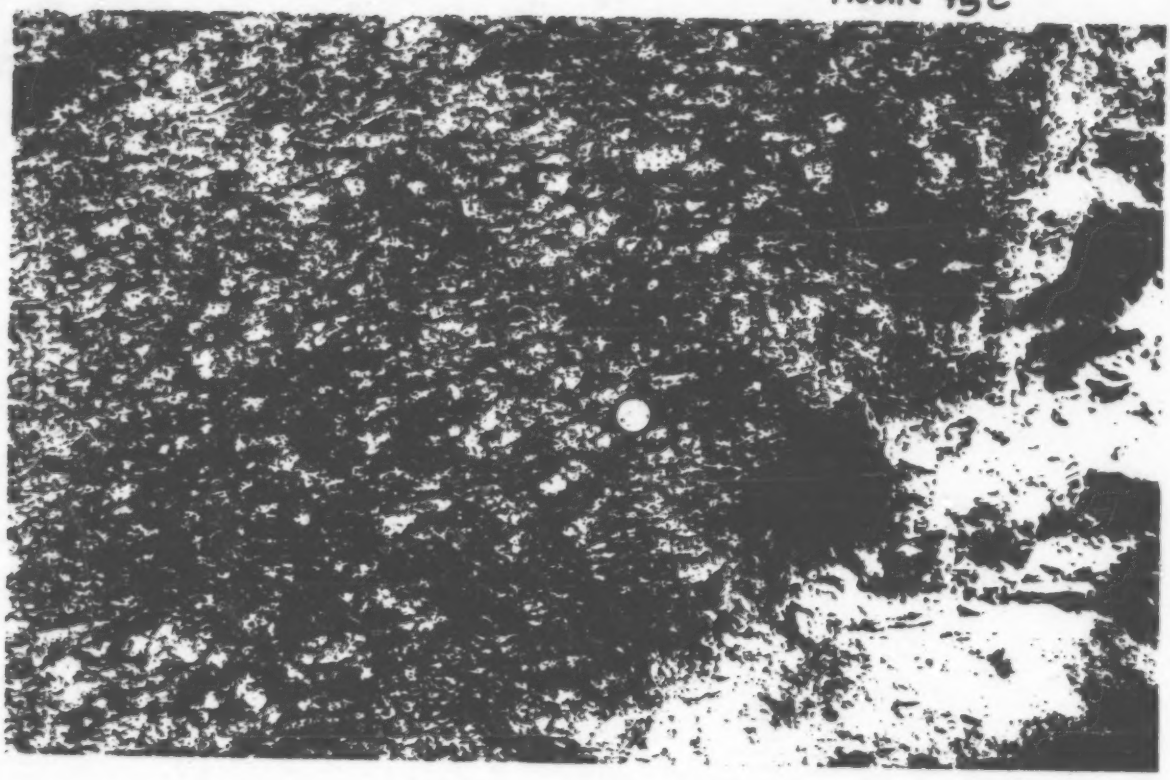


FIGURE 45c



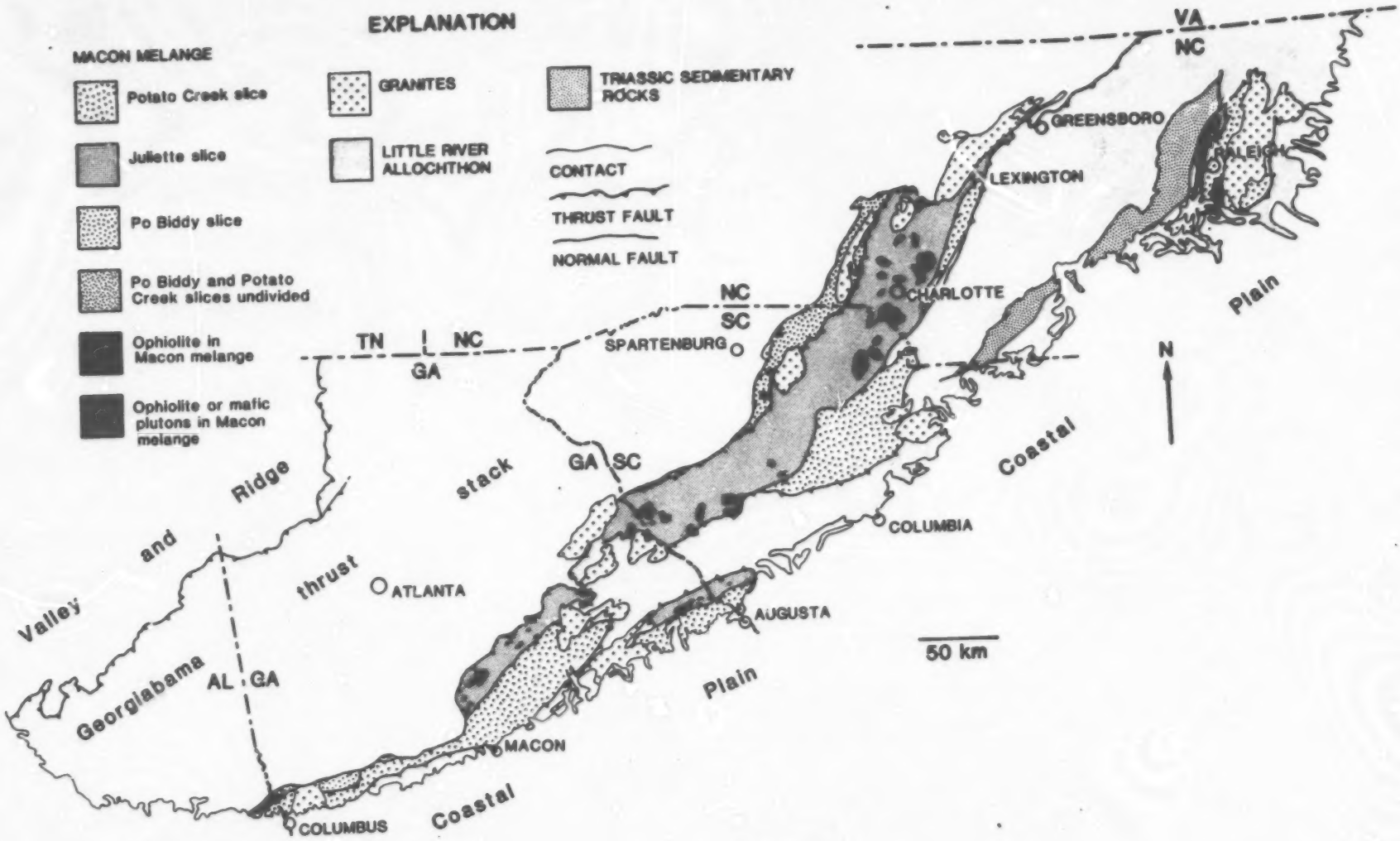

EXPLANATION
MACON MELANGE
Potato Creek slice
Juliette slice
Po Biddy slice
Po Biddy and Potato Creek slices undivided
Ophiolite in Macon melange
Ophiolite or mafic plutons in Macon melange
GRANITES
LITTLE RIVER ALLOCHTHON
TRIASSIC SEDIMENTARY ROCKS
CONTACT
THRUST FAULT
NORMAL FAULT
VA
NC
GREENSBORO
RALEIGH
LEXINGTON
CHARLOTTE
NC
SC
SPARTENBURG
TN
NC
GA
GA
SC
Ridge
and
Valley
thrust
stack
ATLANTA
Georgiabama
AL
GA
Coastal
Plain
COLUMBIA
AUGUSTA
MACON
COLUMBUS
Coastal
Plain
N
50 km

FIGURE 46

FIGURE 47A

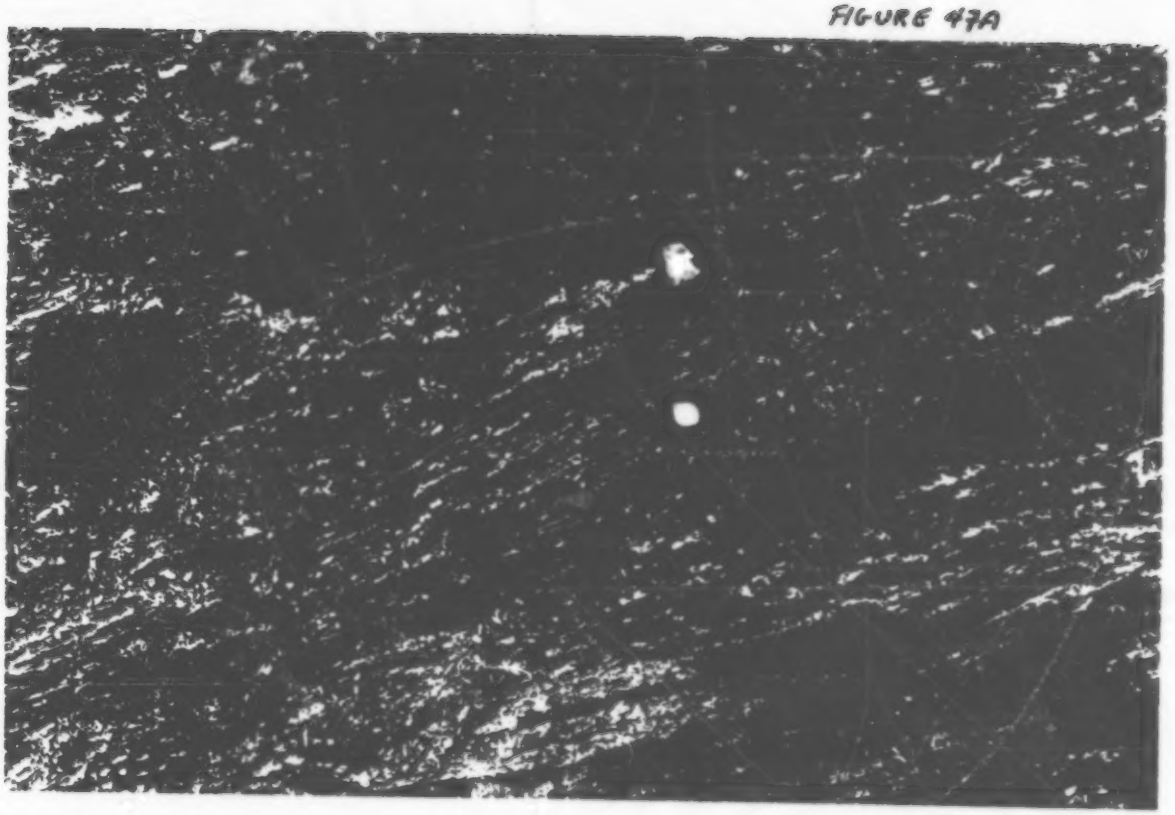


FIGURE 47B

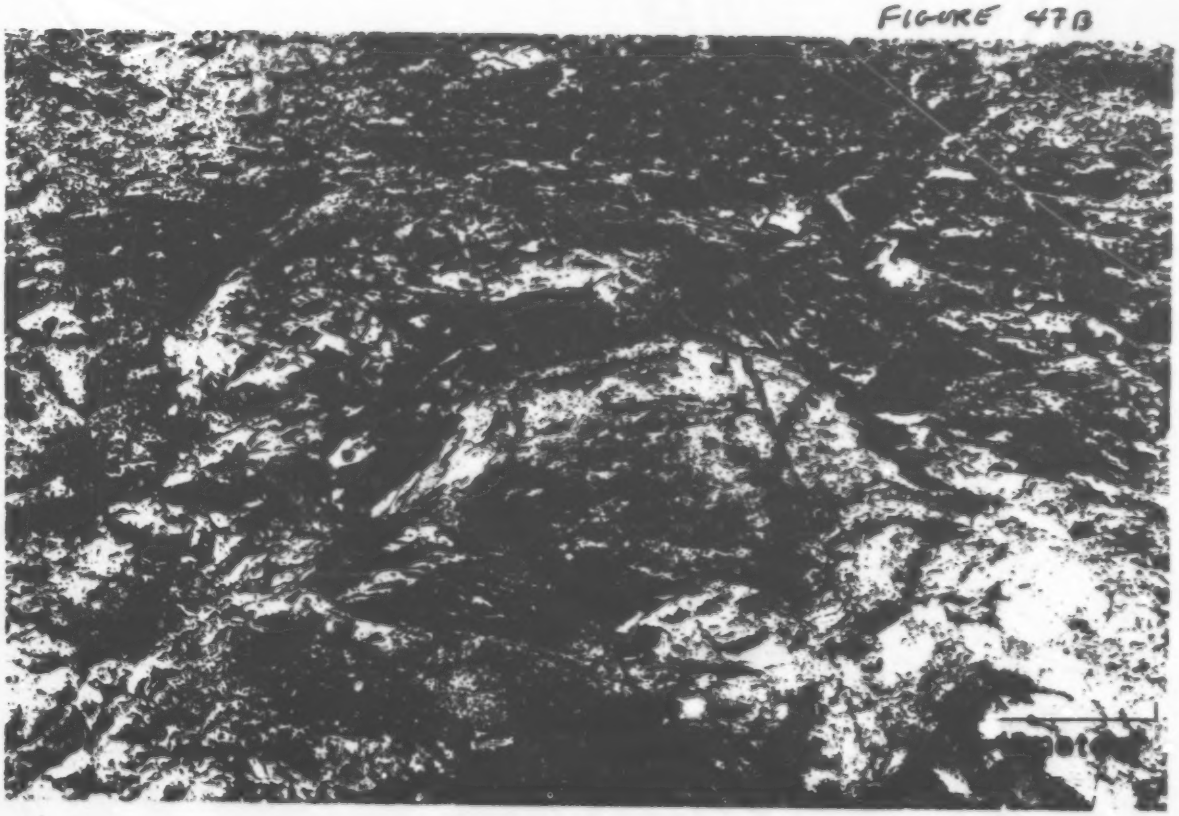


FIGURE 47C

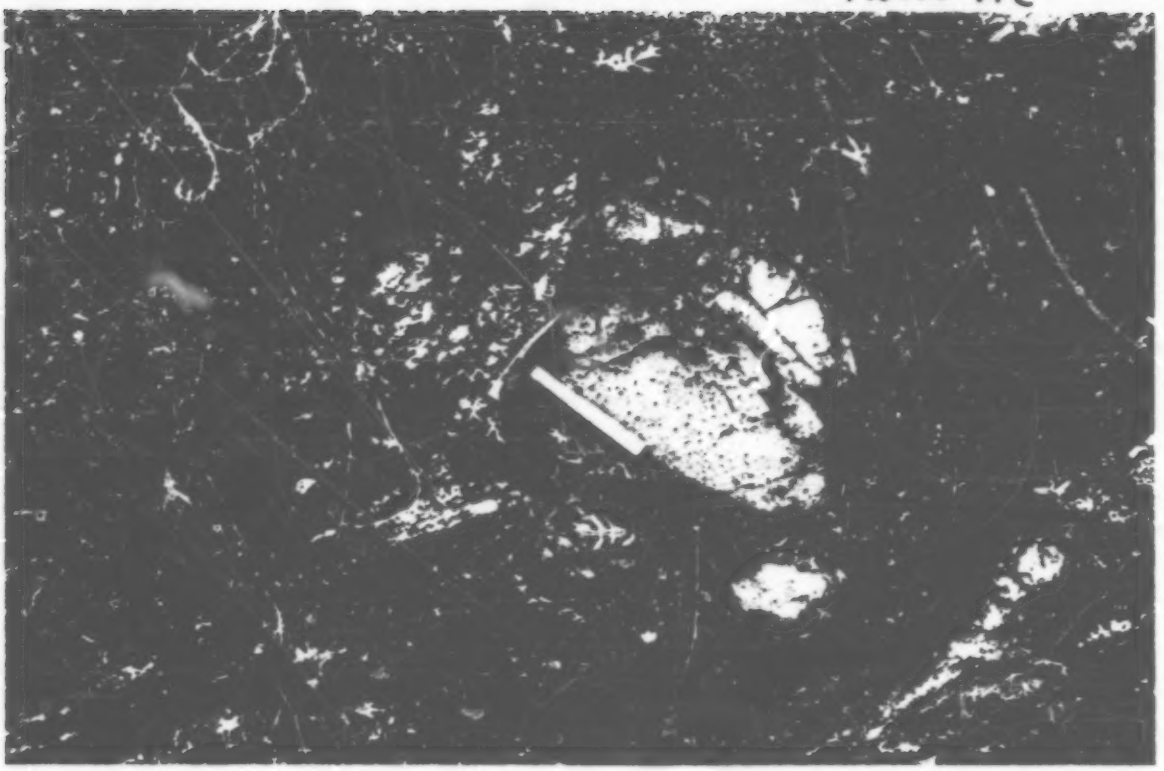


FIGURE 47D

FIGURE 47E

FIGURE 47F

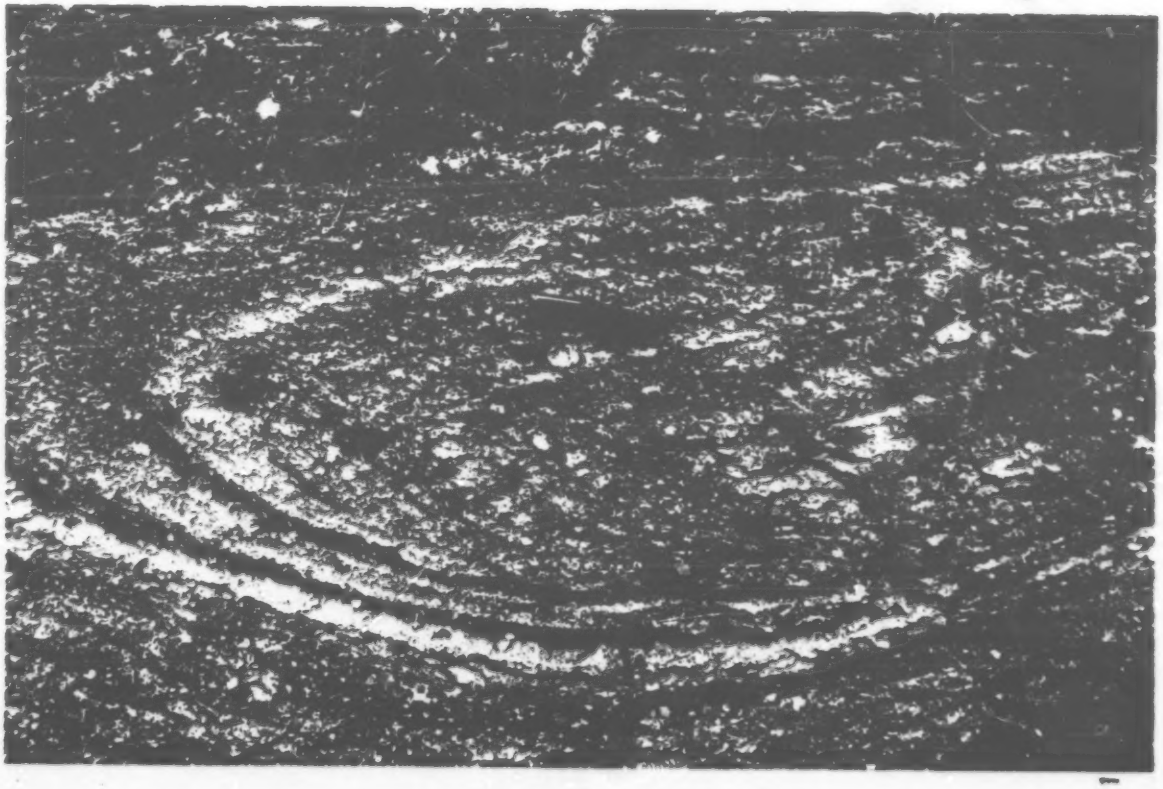


FIGURE 47G

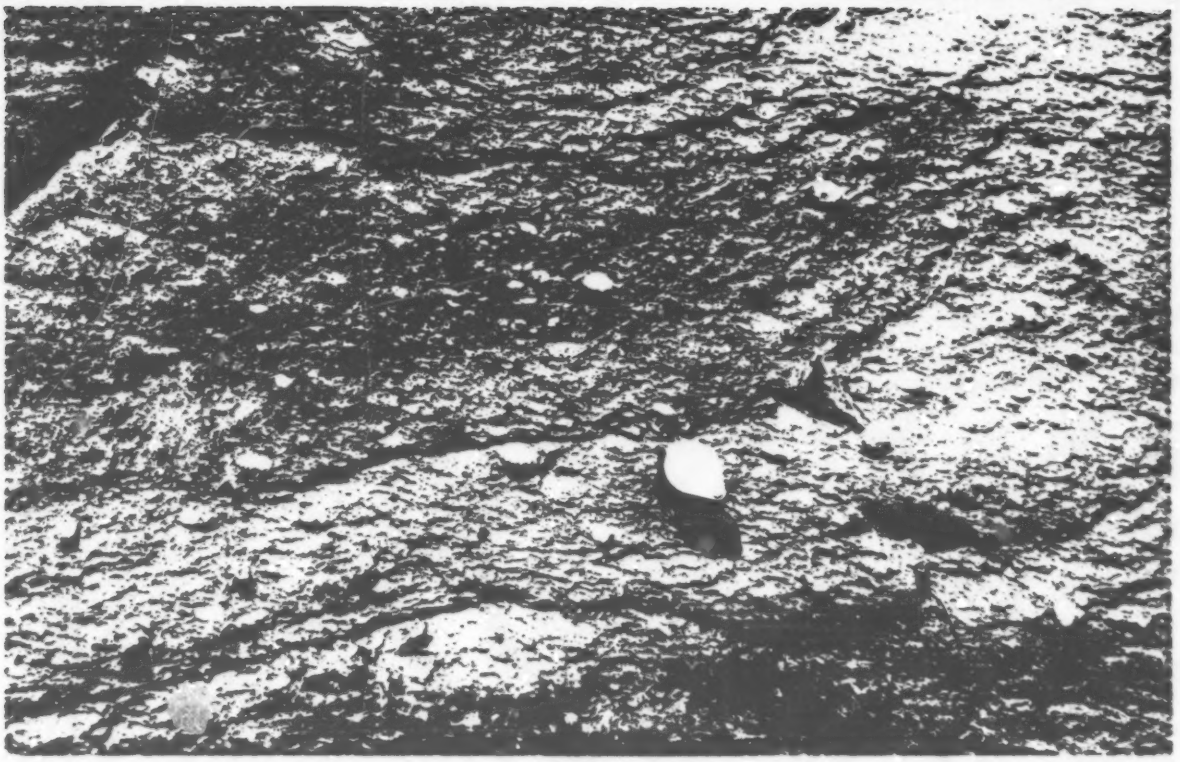


FIGURE 48A

FIGURE 48B

FIGURE 48C

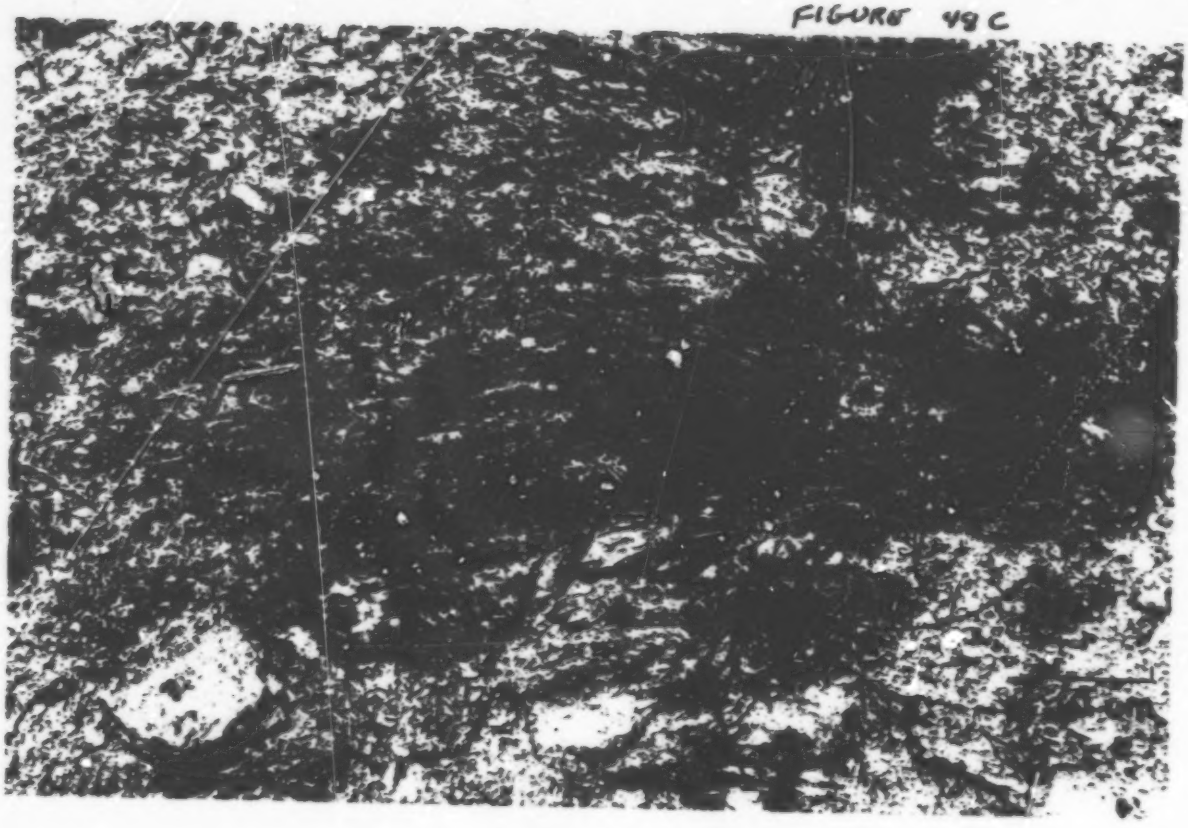


FIGURE 48D

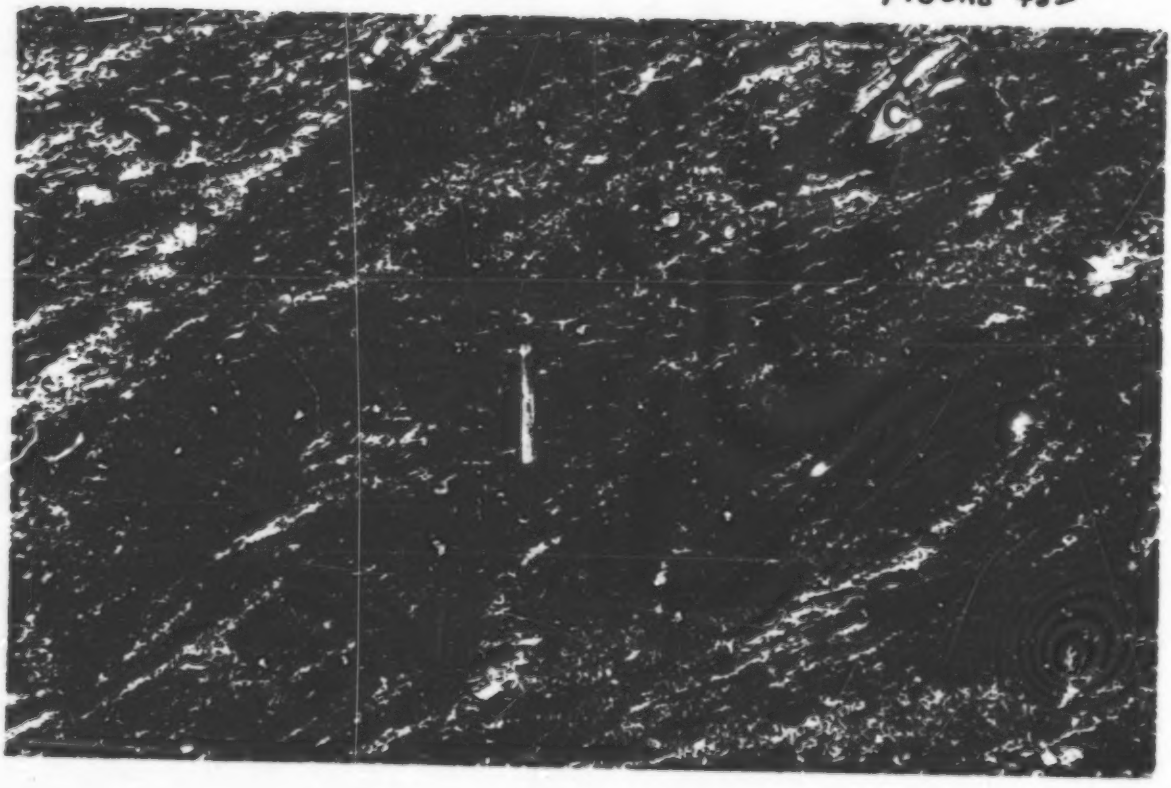


FIGURE 44B

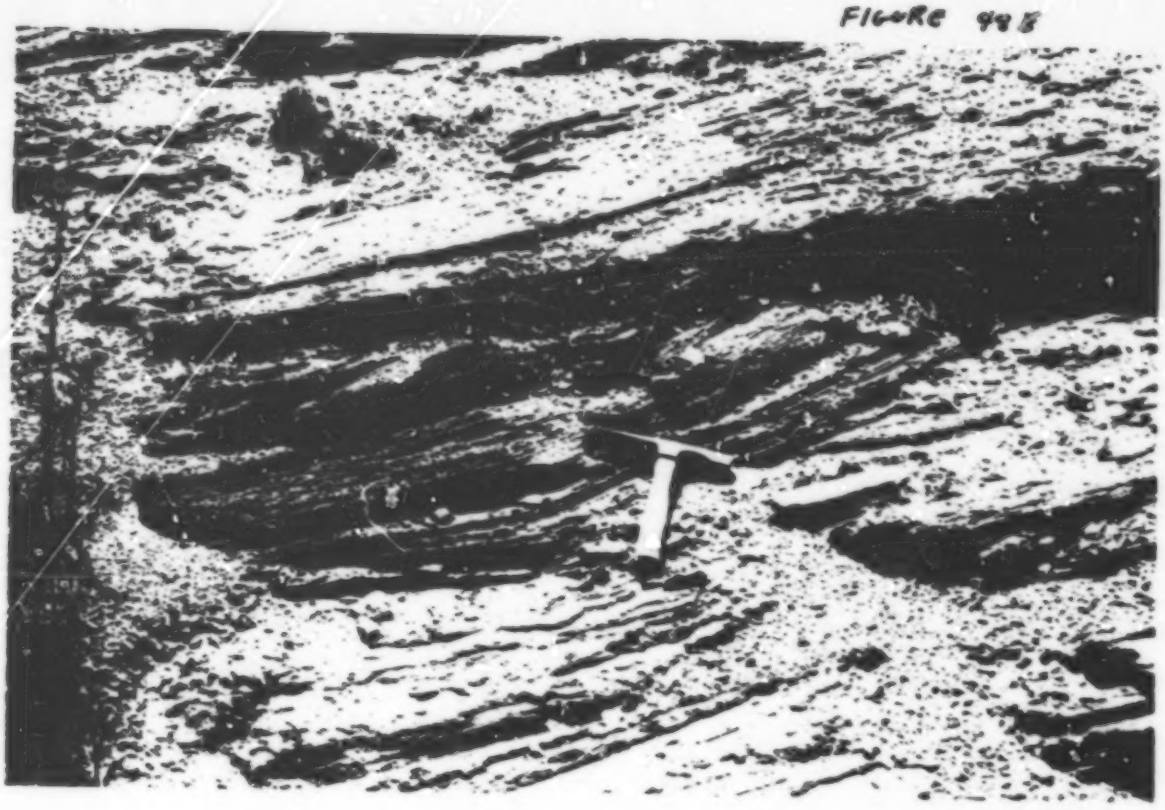


FIGURE 49A

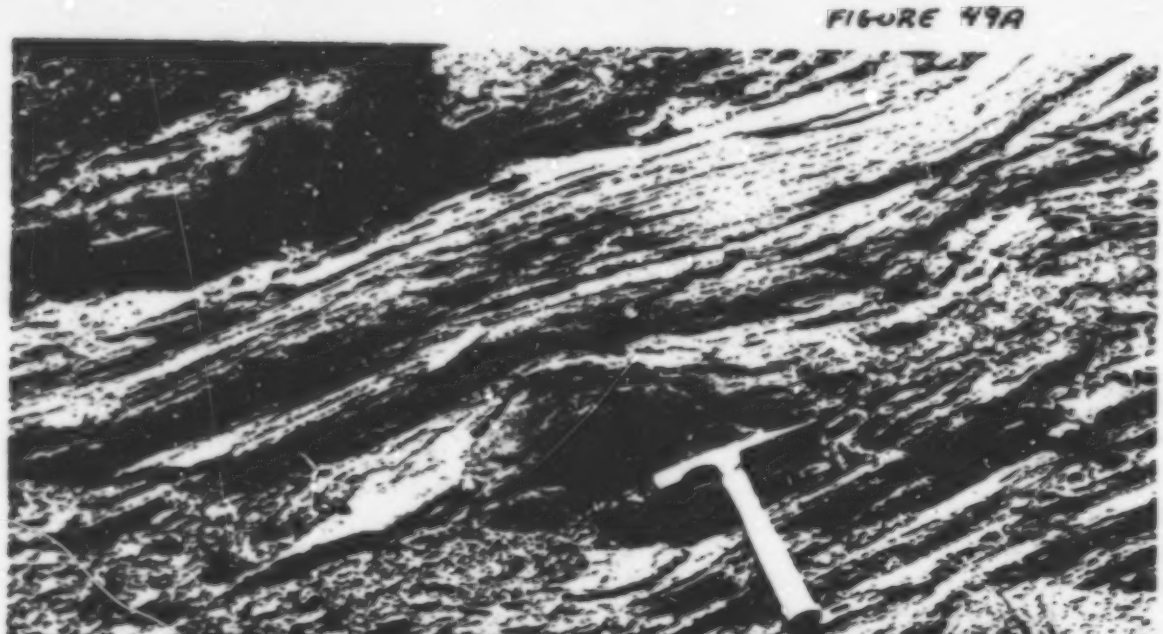


FIGURE 49B

FIGURE 49C

FIGURE 49D

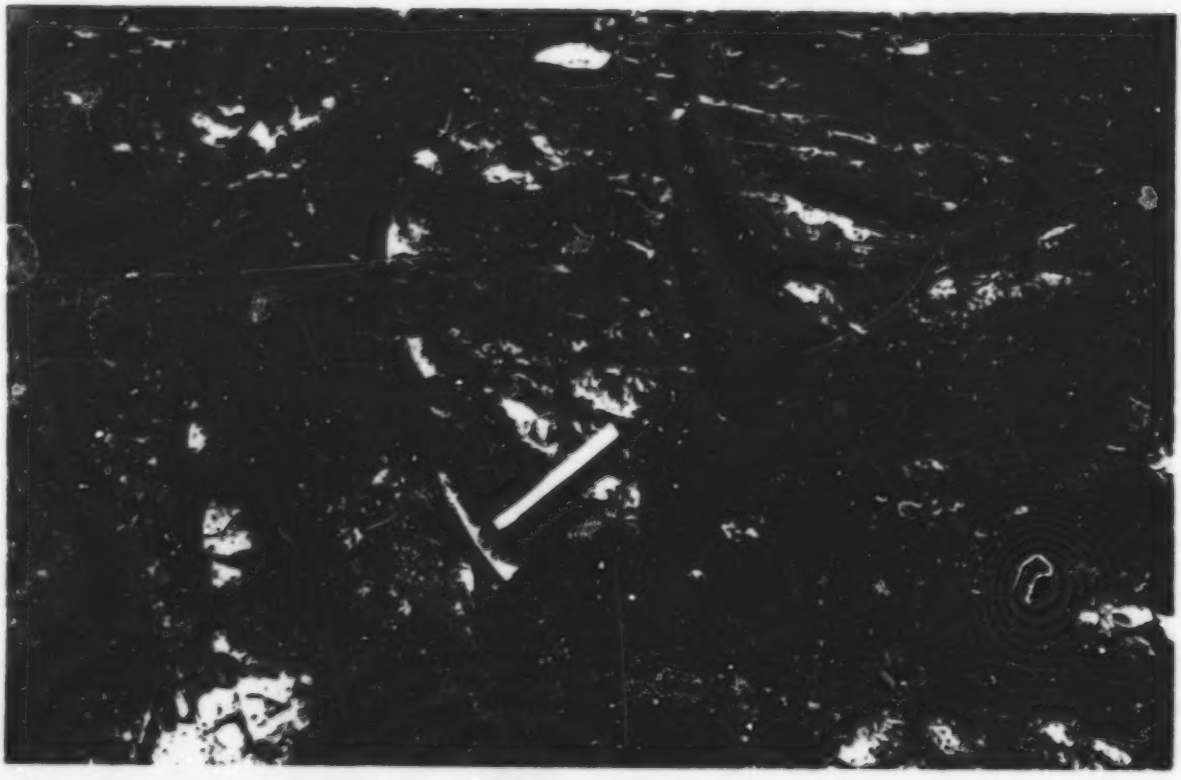


FIGURE 49E

FIGURE 49F

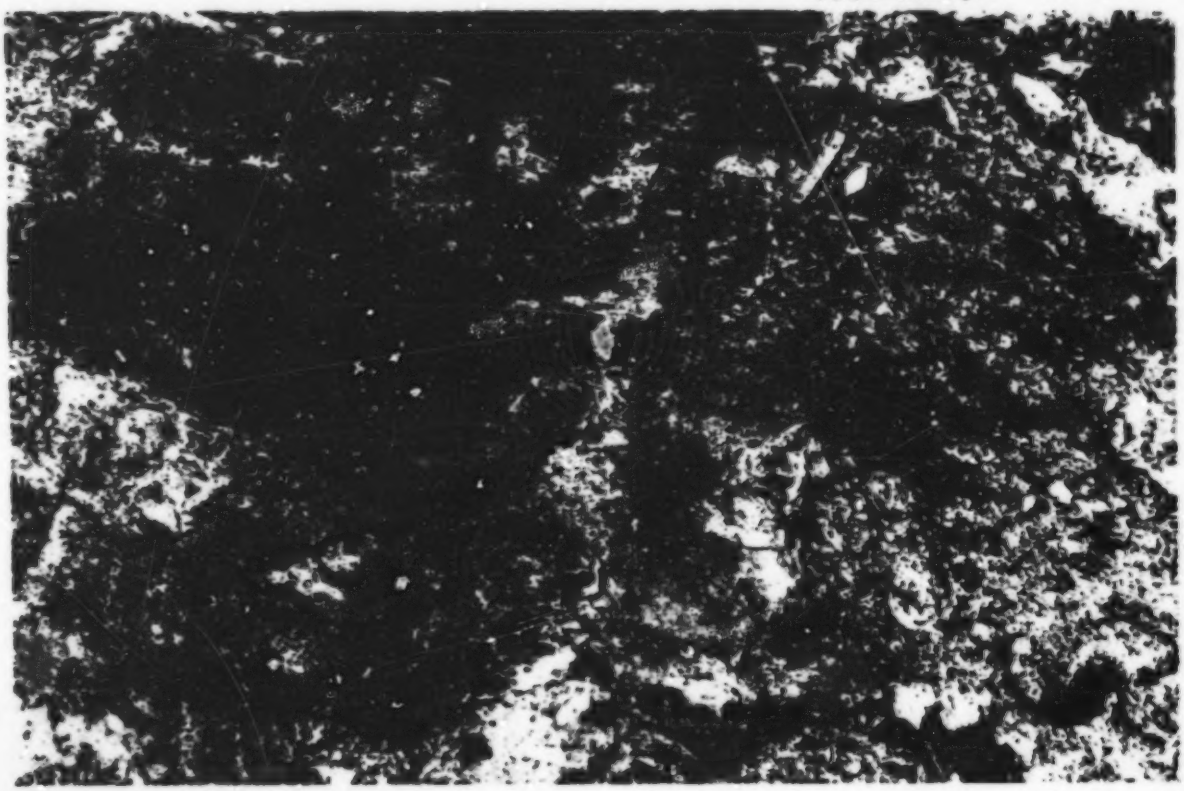


FIGURE 49G

FIGURE 49H

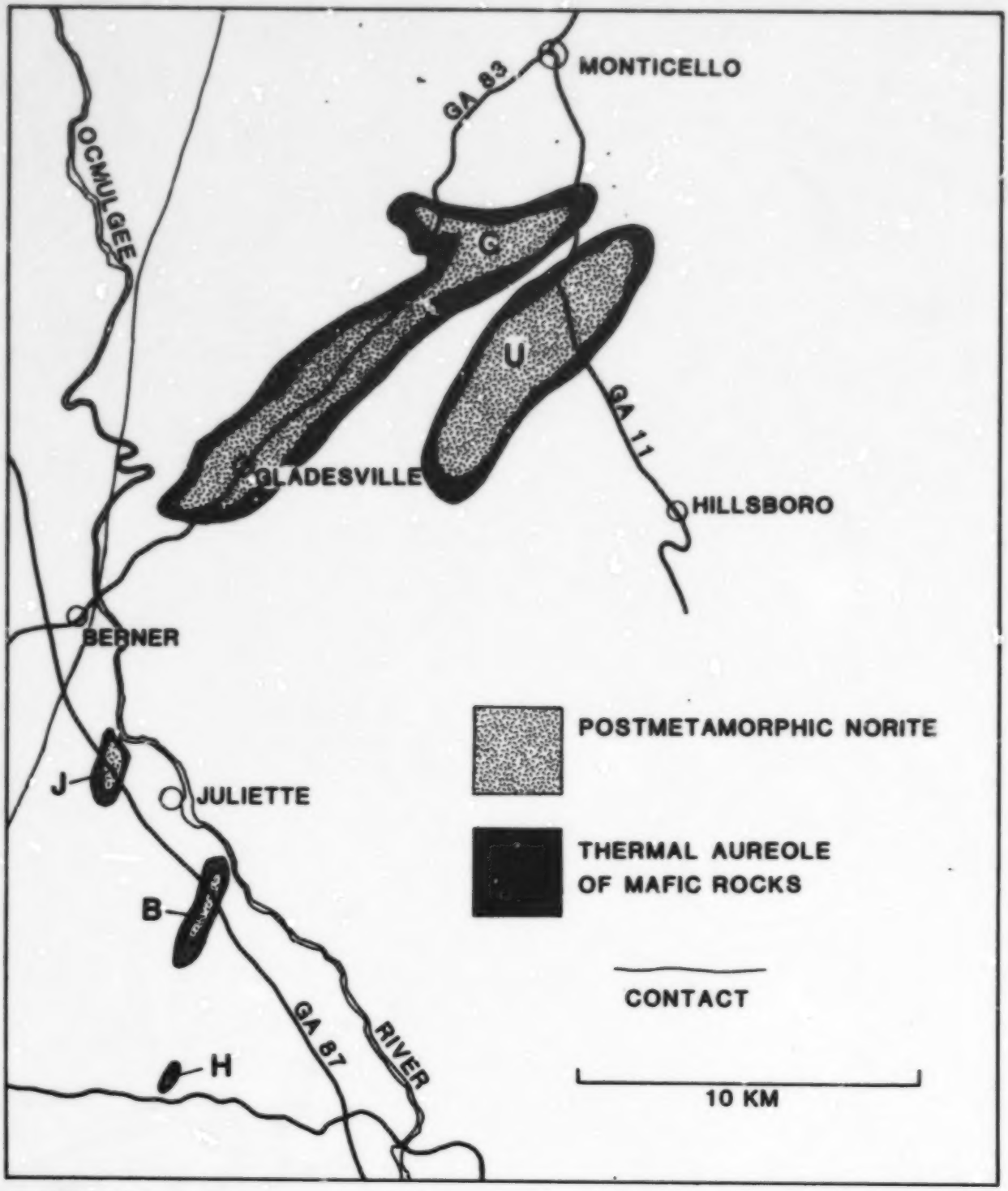

MONTICELLO
GA 83
OCMULGEE
G
U
GA 11
GLADESVILLE
HILLSBORO
BERNER
J
JULIETTE
B
H
GA 87
RIVER
POSTMETAMORPHIC NORITE
THERMAL AUREOLE
OF MAFIC ROCKS
CONTACT
10 KM

FIGURE 50

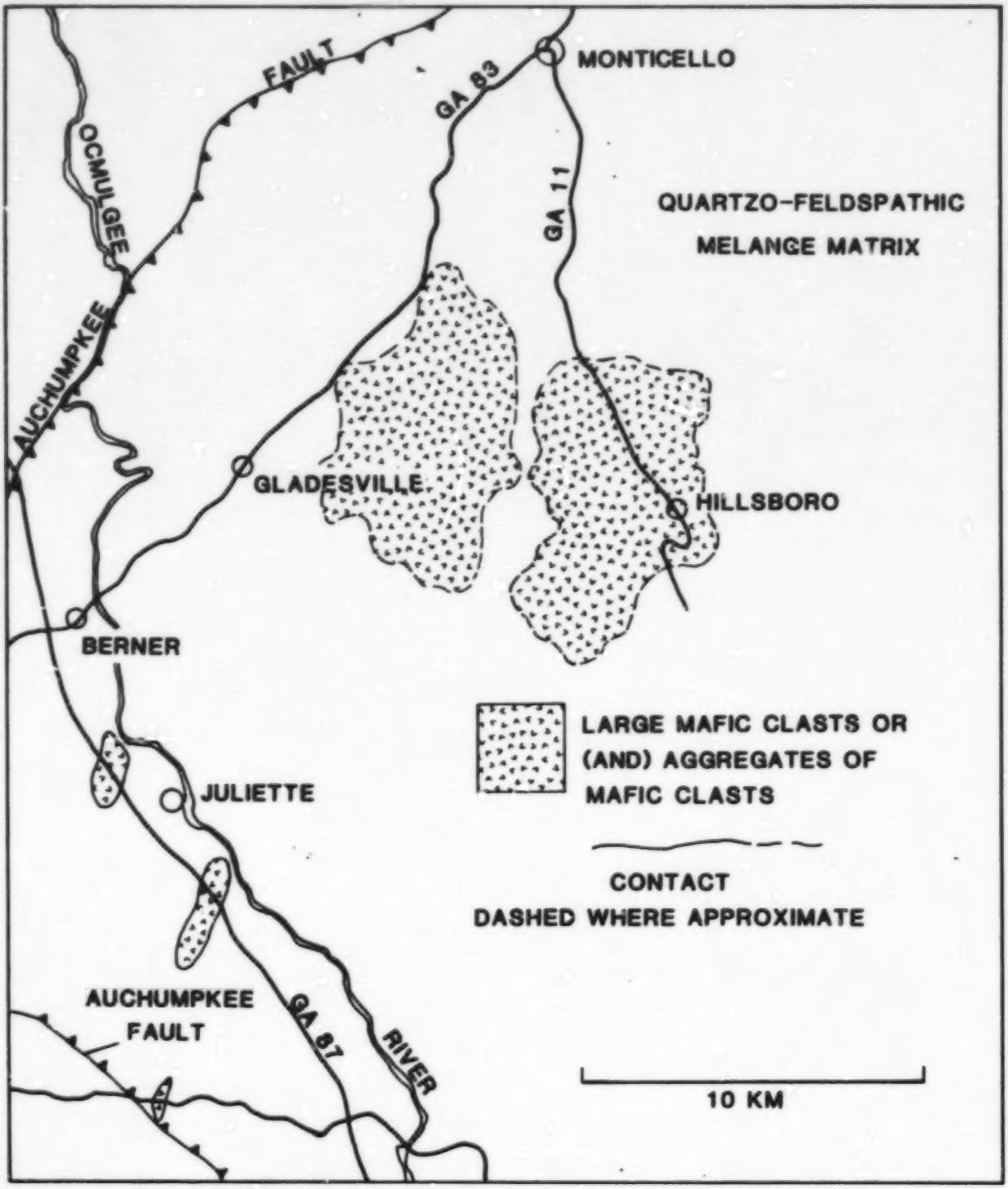

FAULT
OCMULGEE
AUCHUMPKEE
GA 83
GA 11
MONTICELLO
QUARTZO-FELDSPATHIC
MELANGE MATRIX
GLADESVILLE
HILLSBORO
BERNER
JULIETTE
LARGE MAFIC CLASTS OR
(AND) AGGREGATES OF
MAFIC CLASTS
CONTACT
DASHED WHERE APPROXIMATE
AUCHUMPKEE
FAULT
GA 87
RIVER
10 KM

FIGURE 51

FIGURE #52

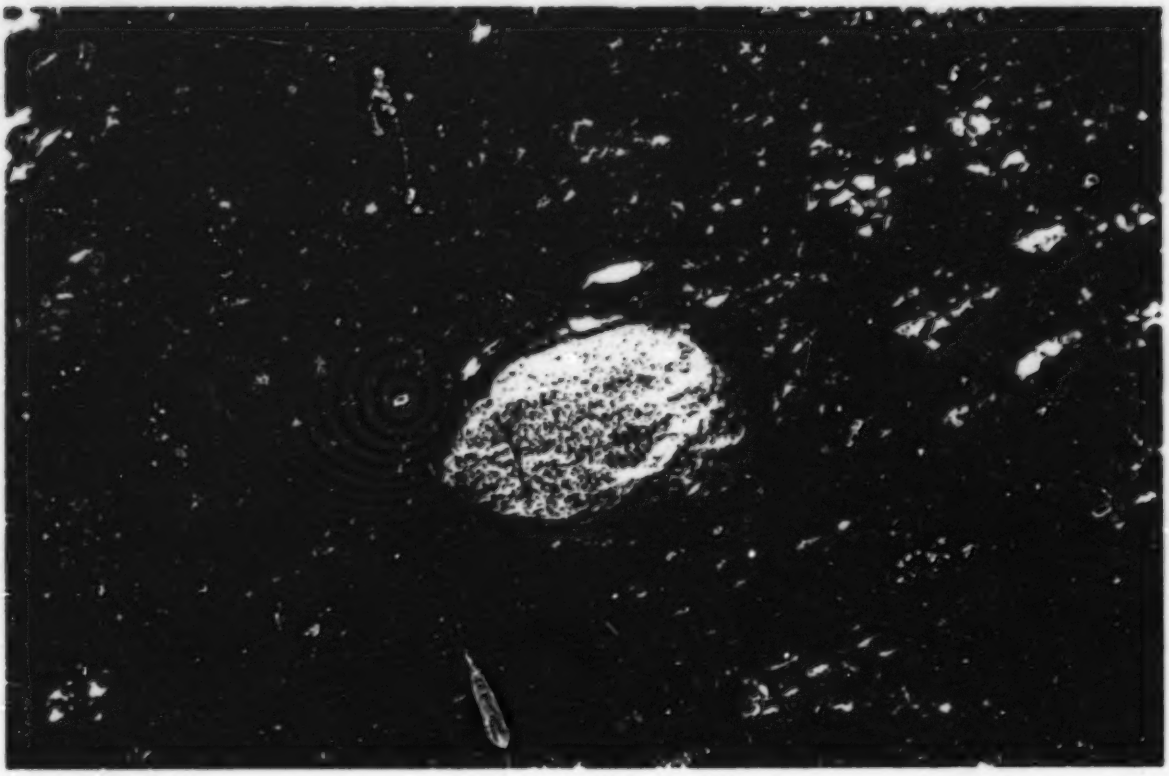


FIGURE 53

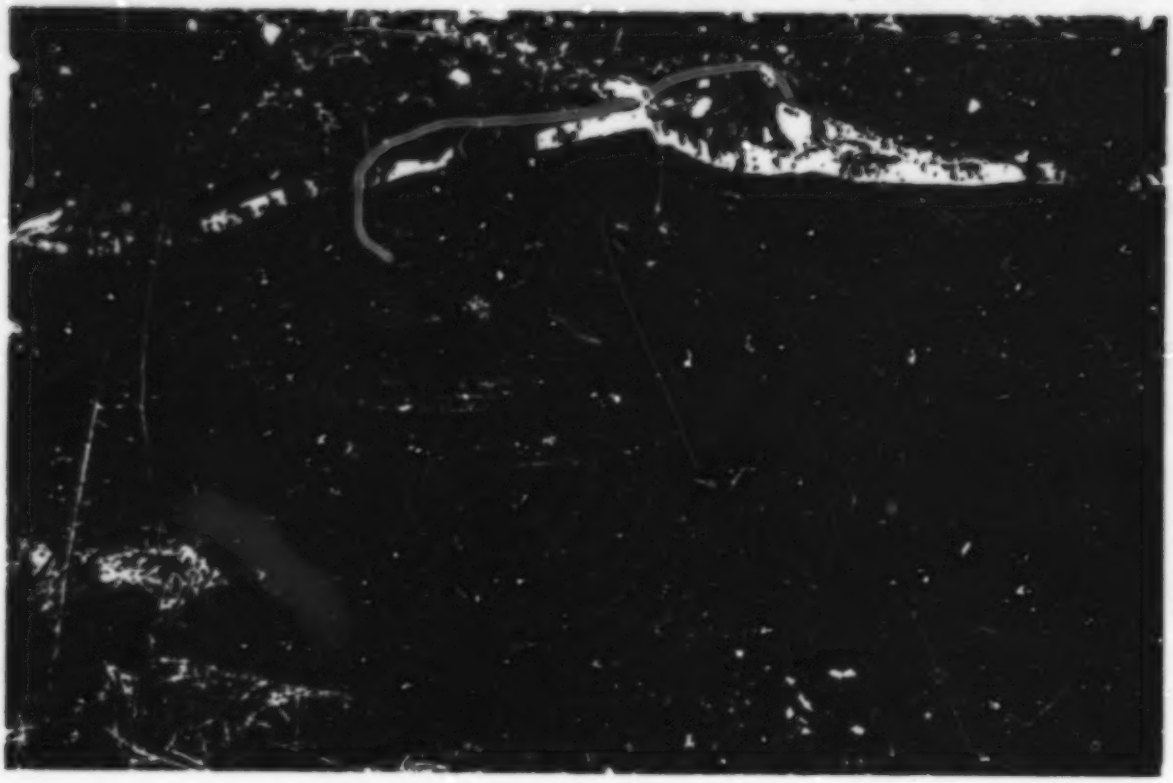


FIGURE 54A

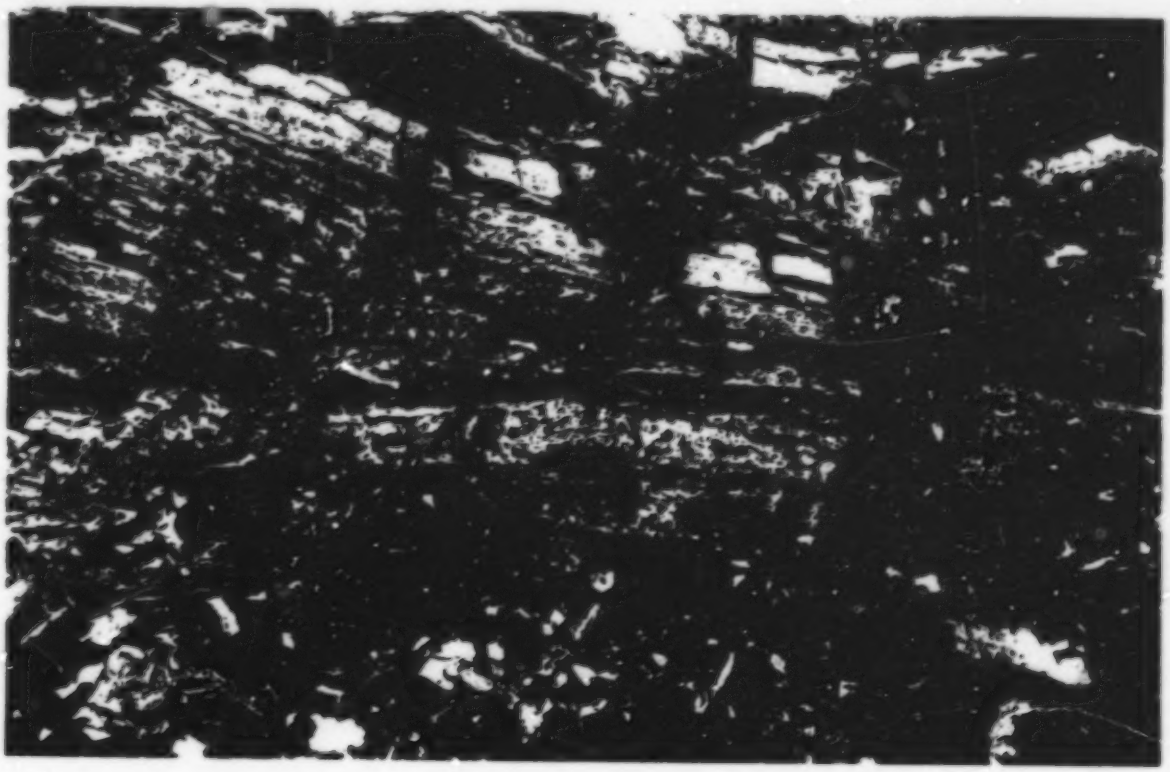


FIGURE 54B

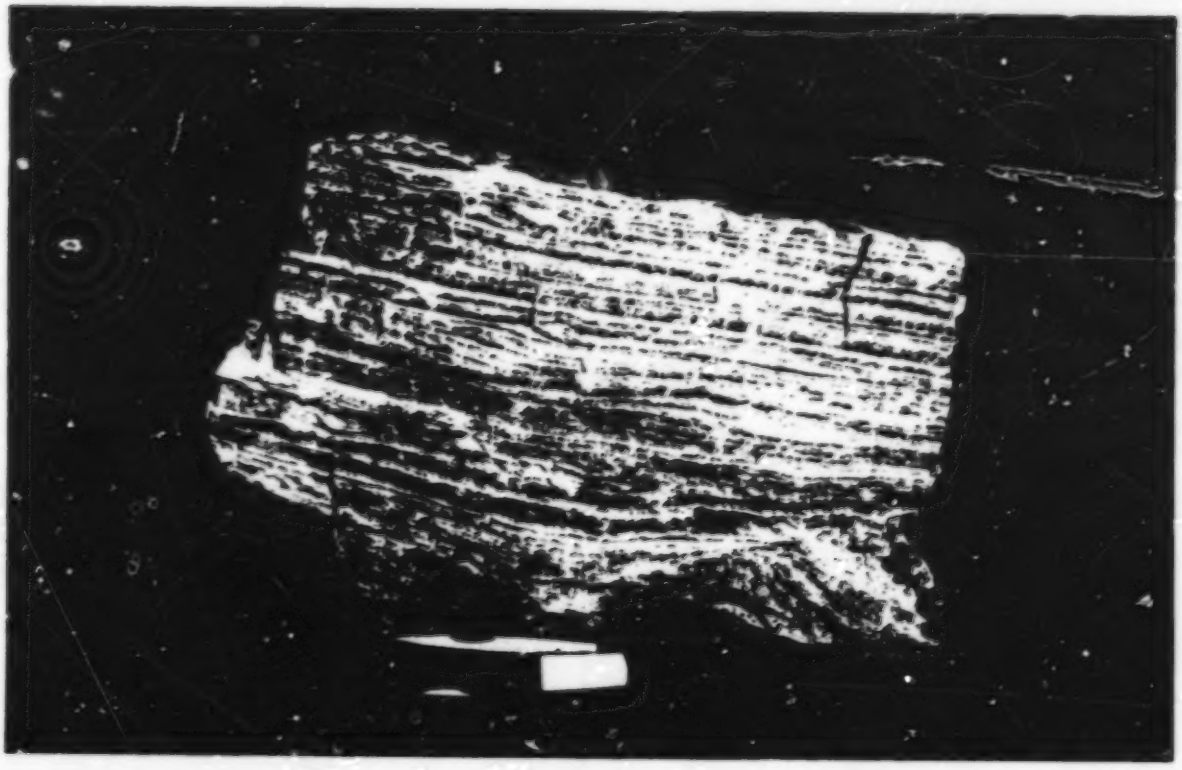


FIGURE 54C

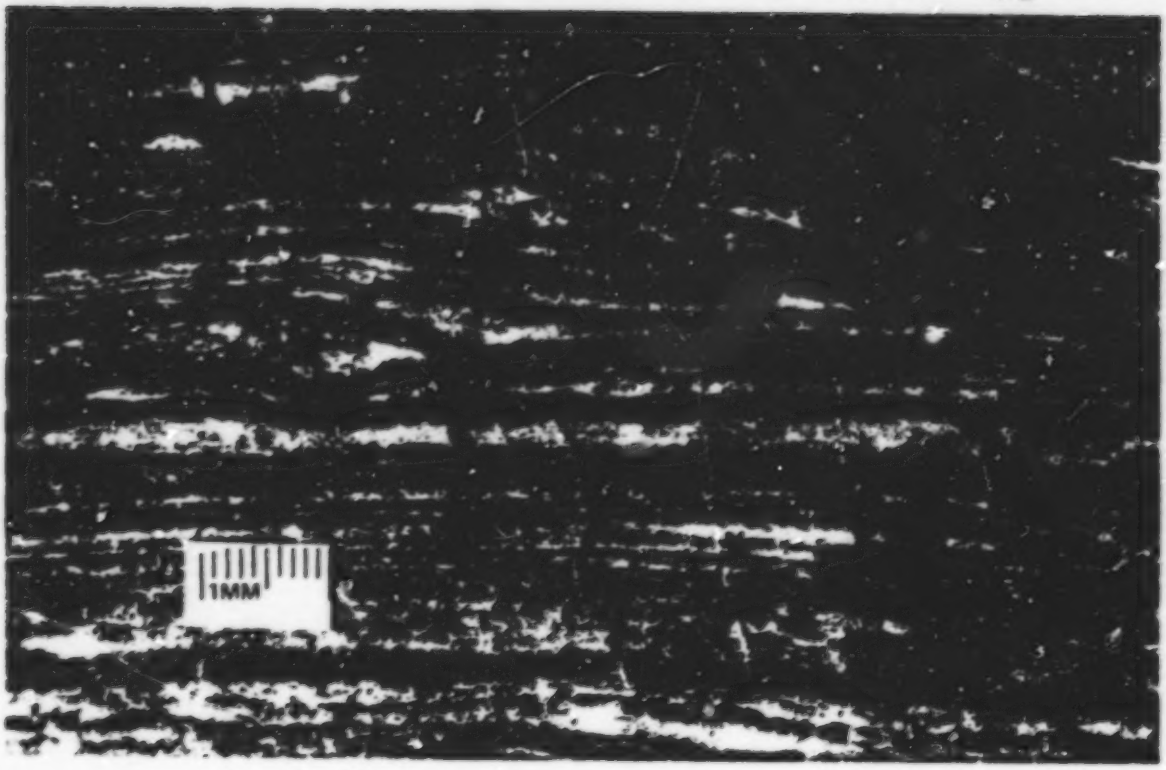


FIGURE 55

FIGURE 56A

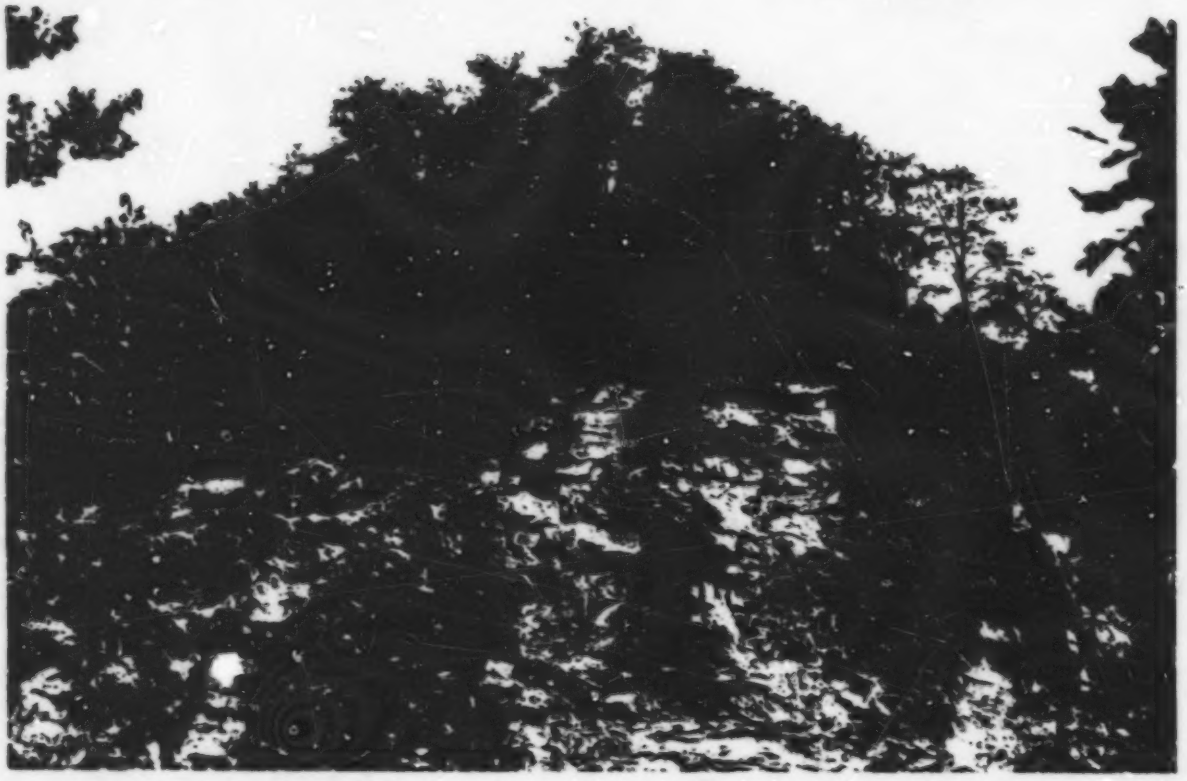
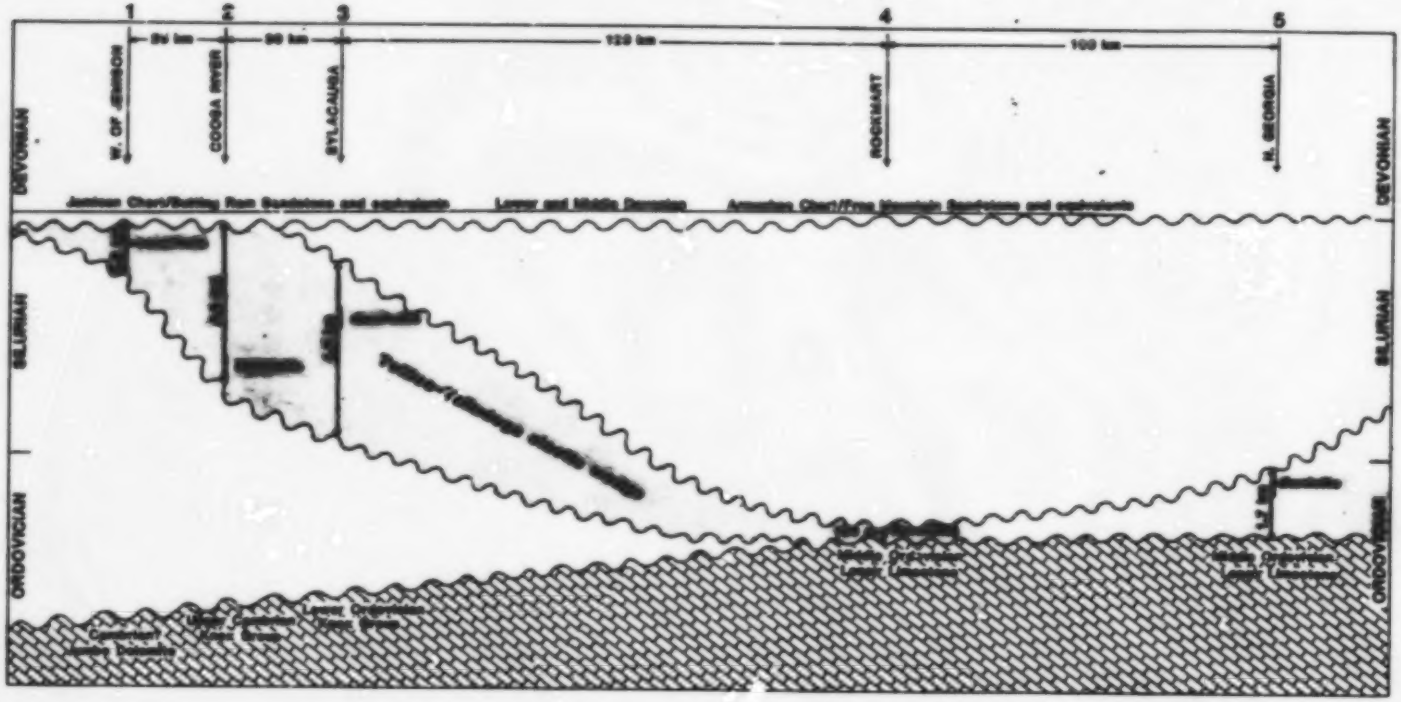
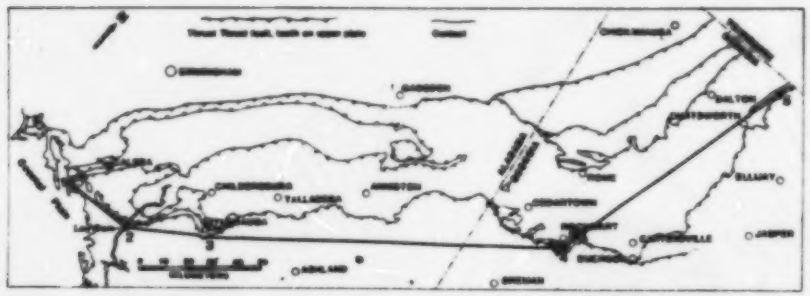


FIGURE 56B

Figure 57


1
2
3
4
5
W. OF JENNISON
COOSA RIVER
SYLACAUGA
ROCKMART
N. GEORGIA
DEVONIAN
SILURIAN
ORDOVICIAN



Figur 58 A

Figur 58B

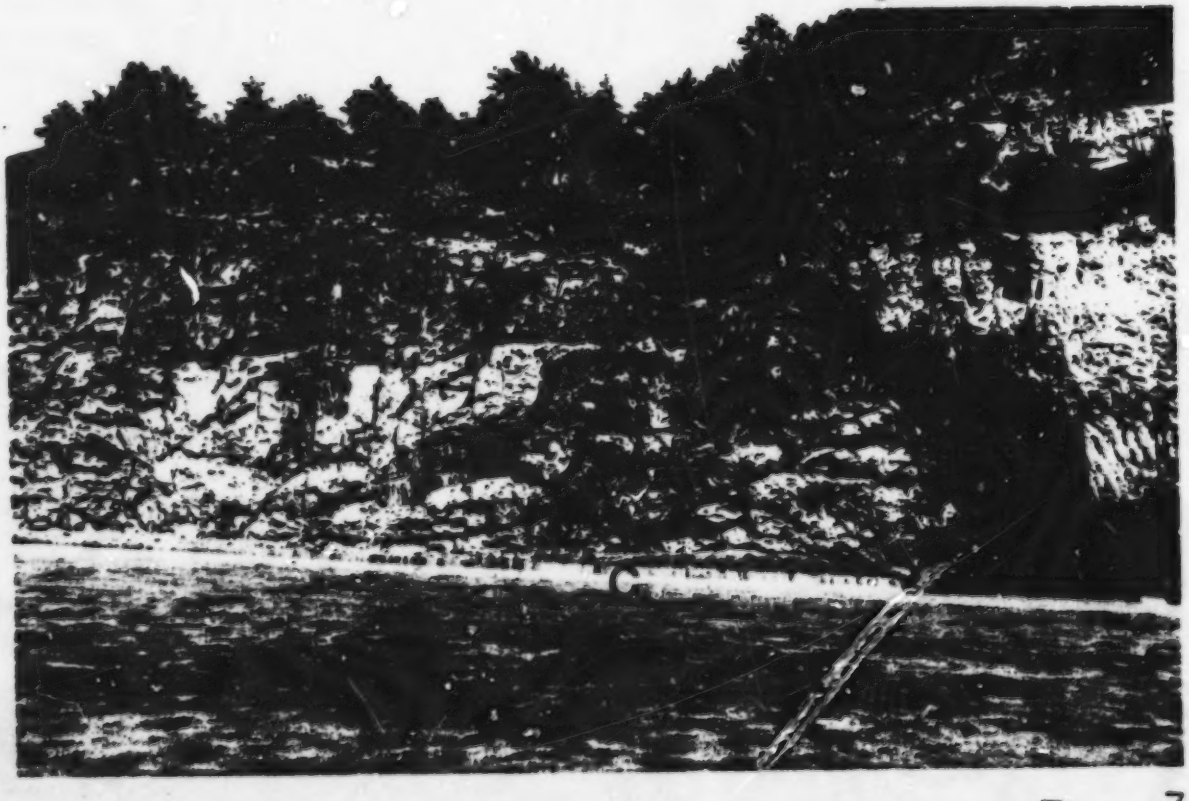


Figure 58C

Figure 58D

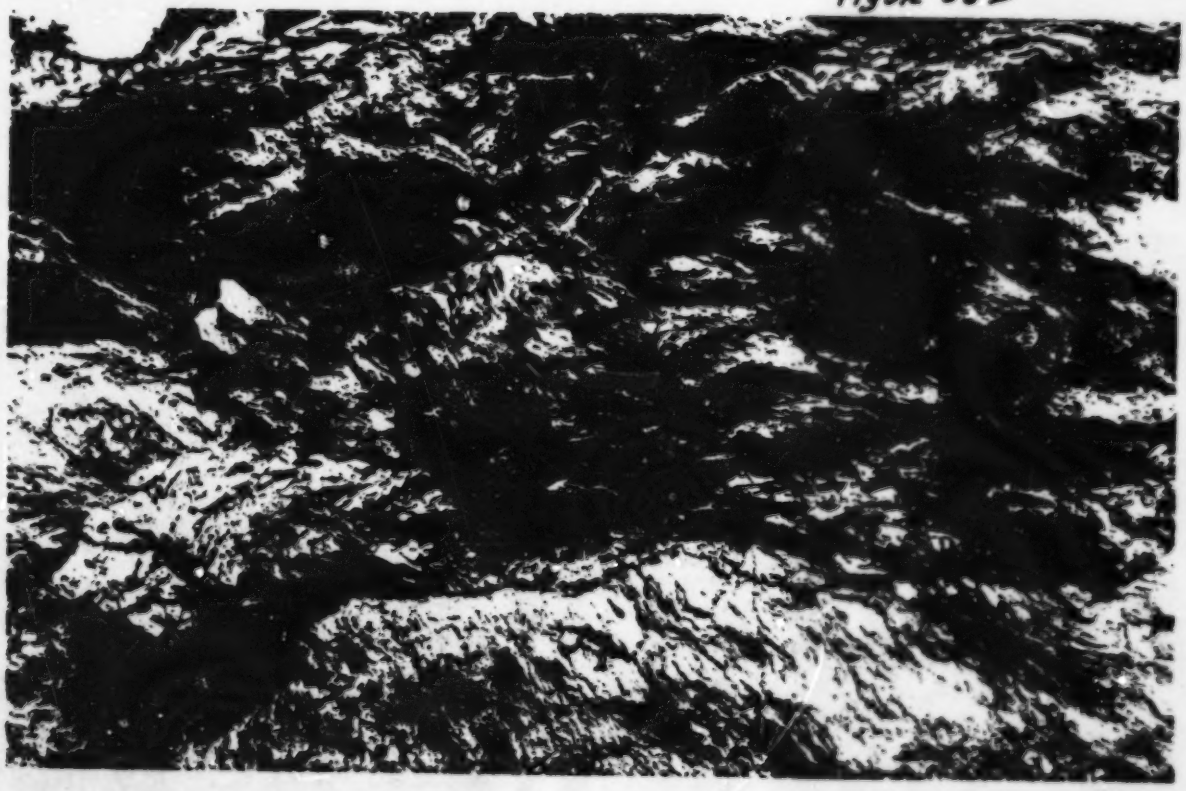
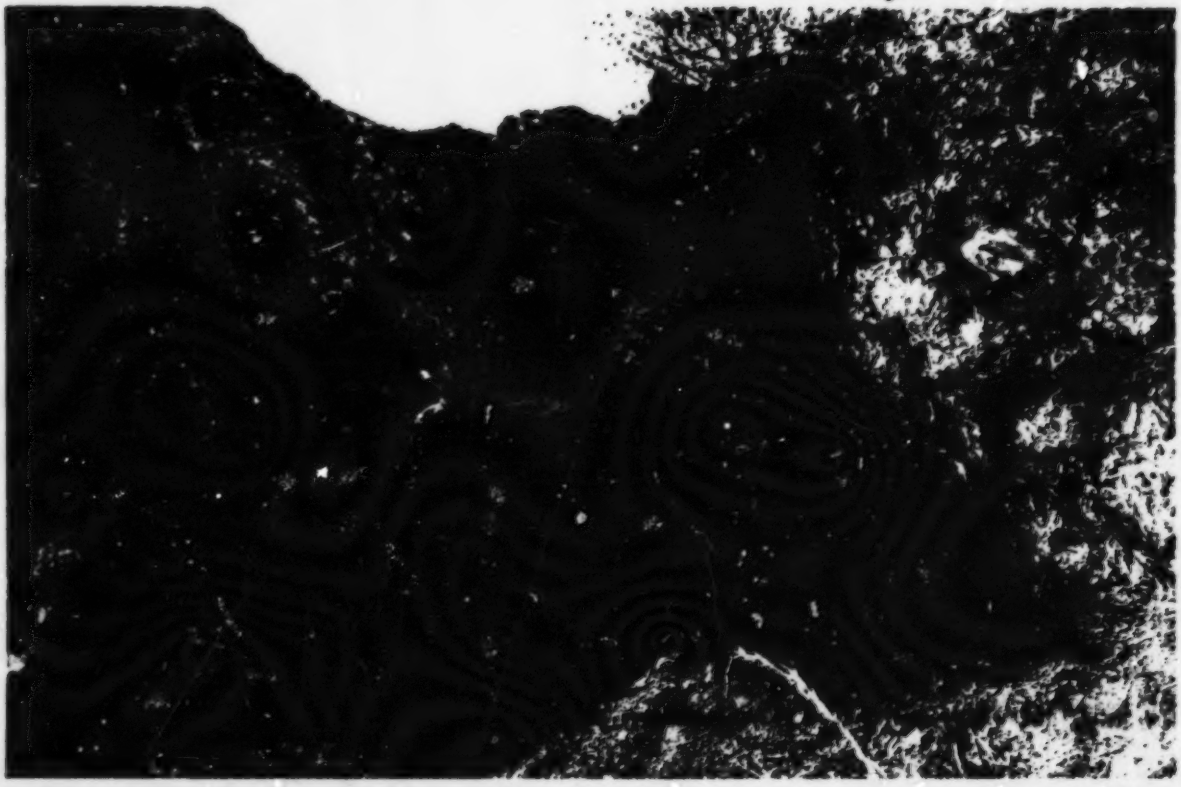


Figure 58E

Figure 58F



Figur 58 G

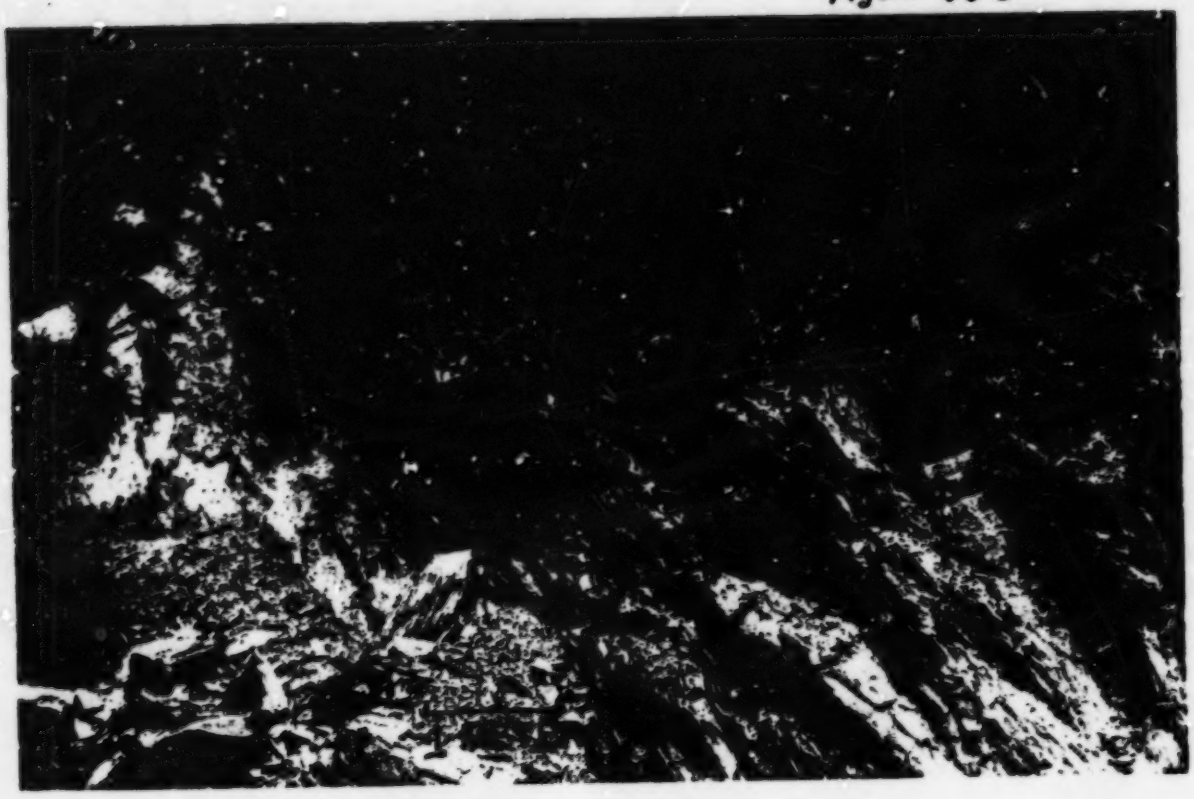


FIGURE 58H

Figure 58 I

Figure 60A

Figure 60B

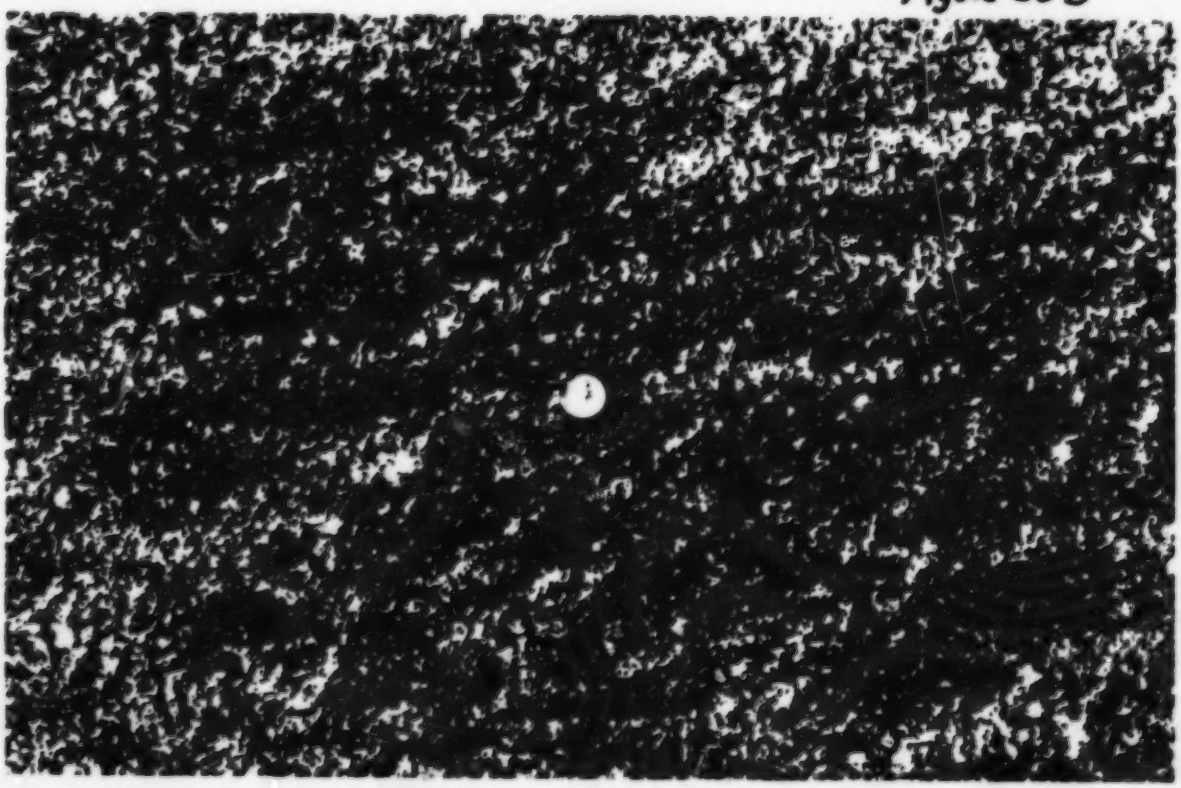
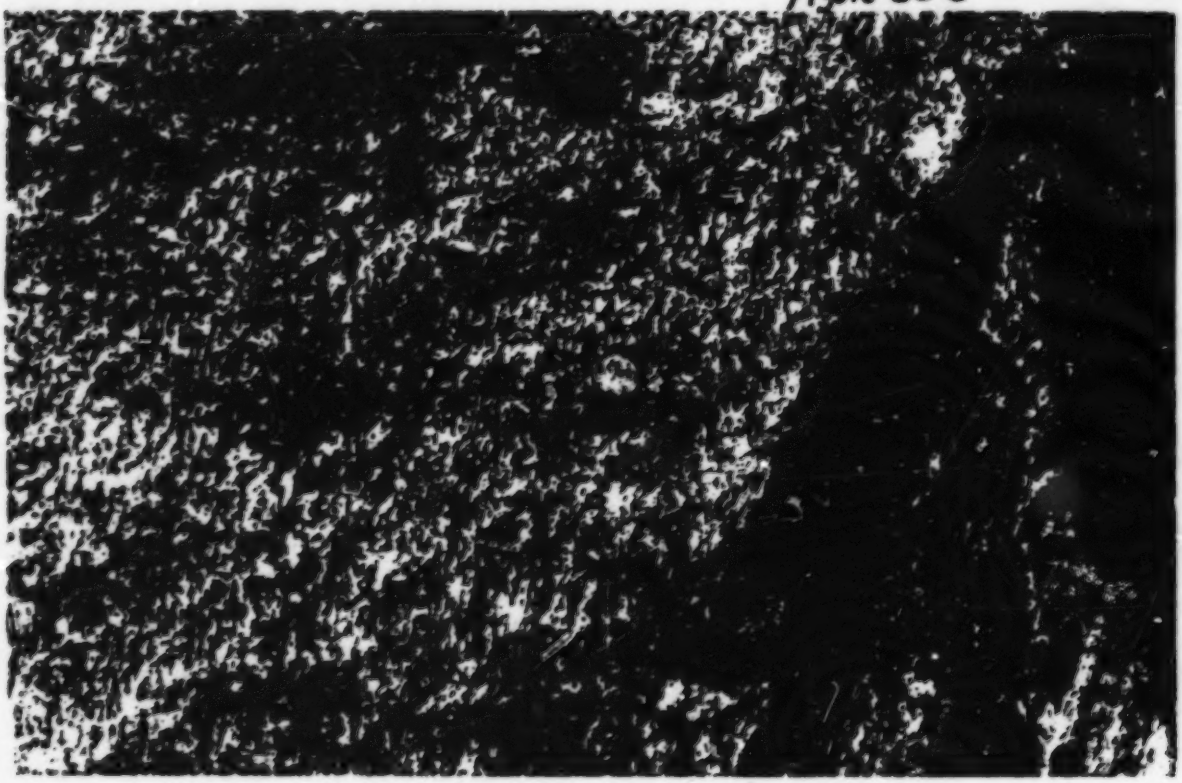


Figure 60C



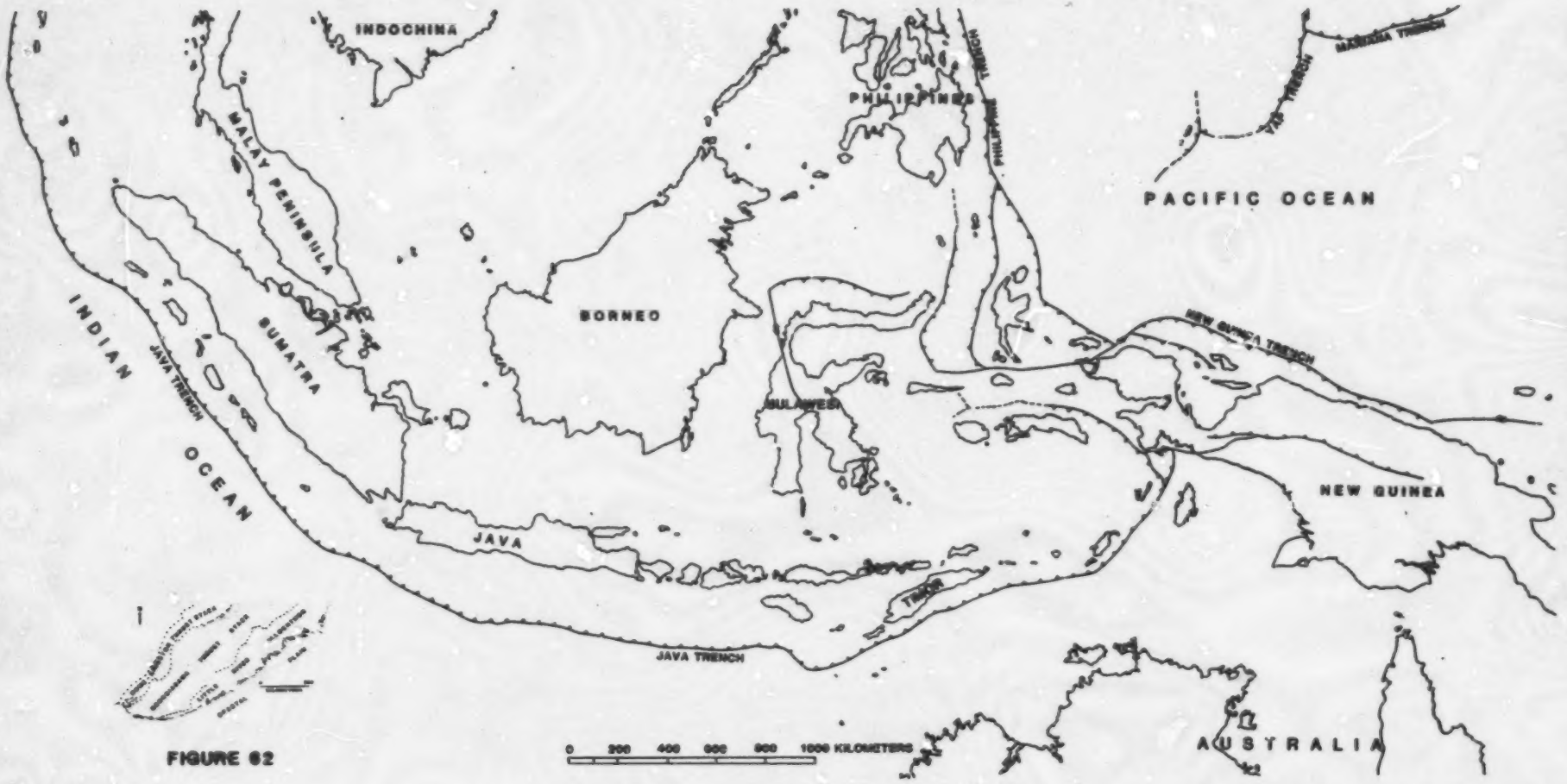
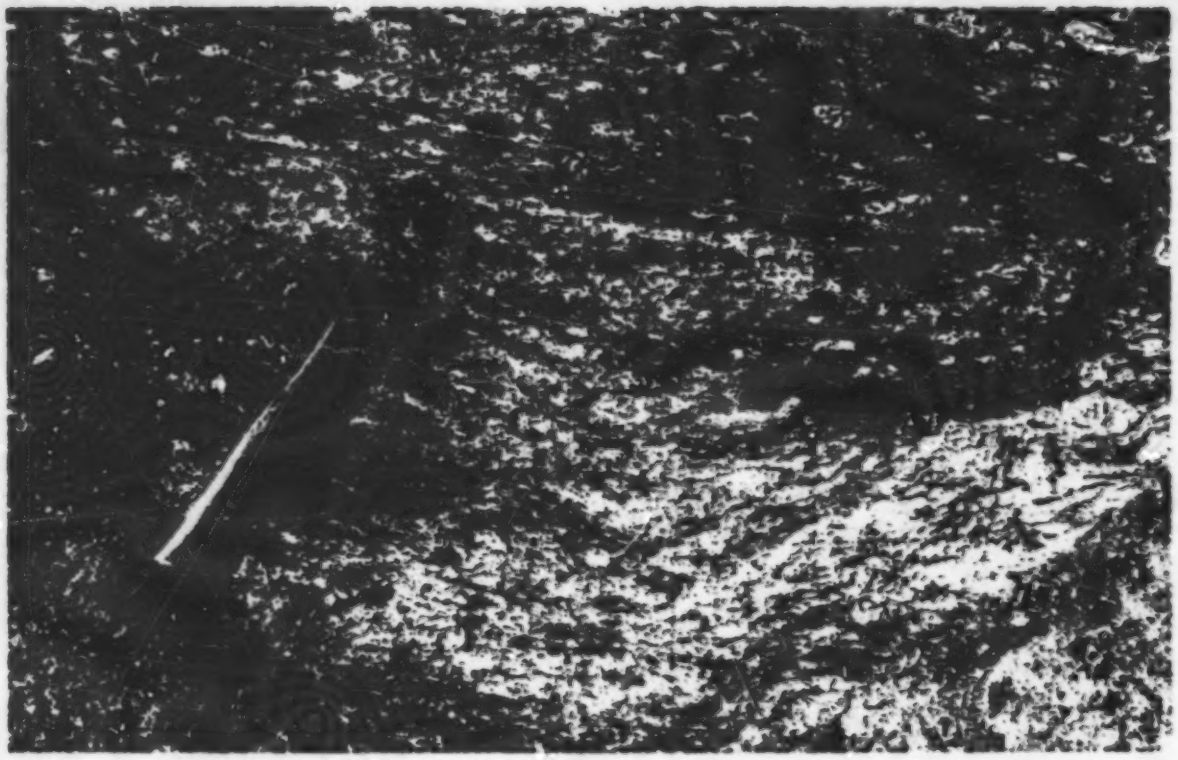

INDOCHINA
MALAY PENINSULA
SUMATRA
INDIAN OCEAN
JAVA TRENCH
BORNEO
PHILIPPINES
PHILIPPINE TRENCH
PACIFIC OCEAN
MARIANA TRENCH
YAP TRENCH
NEW GUINEA TRENCH
CELEBES
NEW GUINEA
JAVA
TIMOR
JAVA TRENCH
AUSTRALIA
0 200 400 600 800 1000 KILOMETERS

FIGURE 62

Figure 63



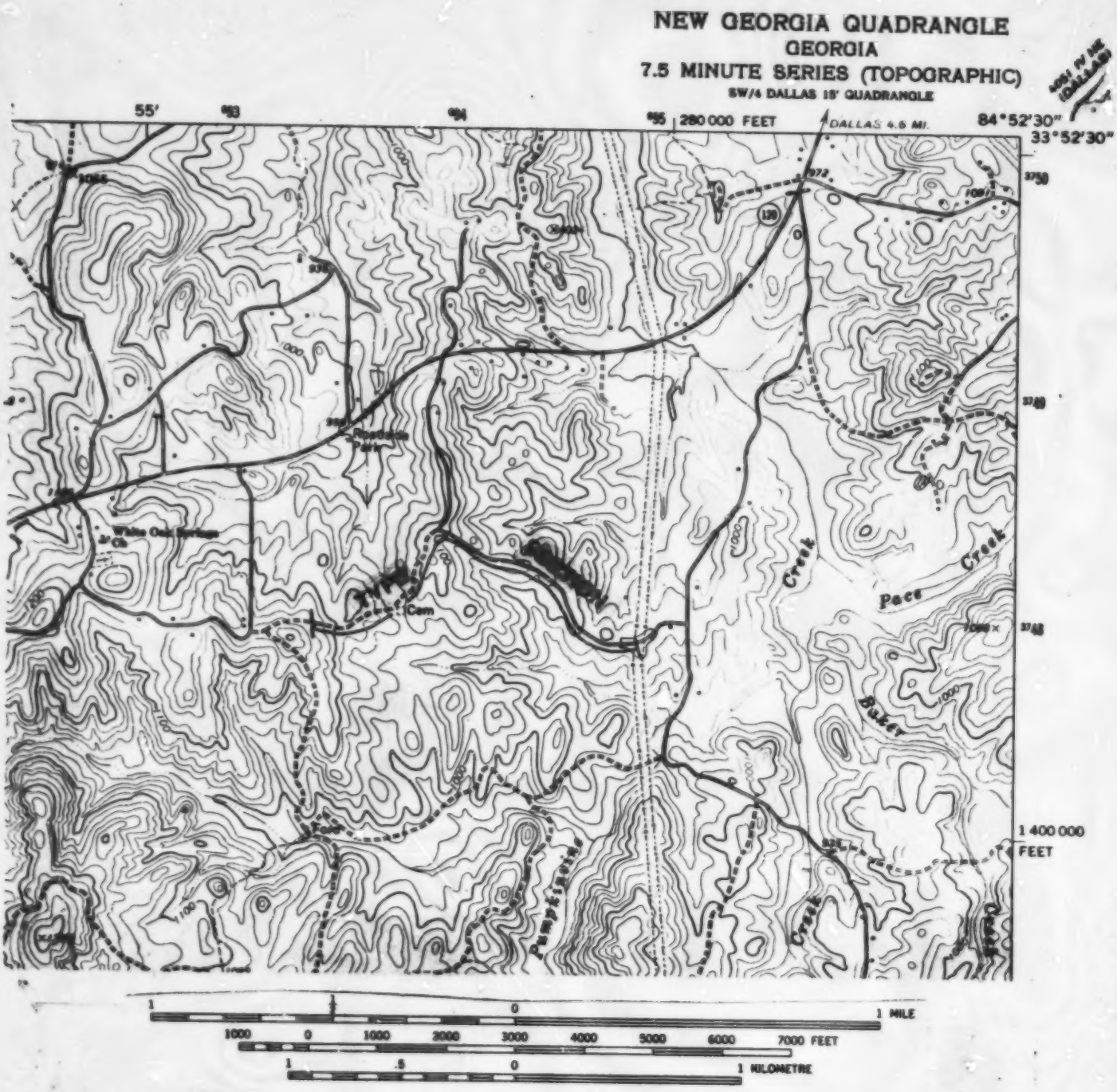

NEW GEORGIA QUADRANGLE
GEORGIA
7.5 MINUTE SERIES (TOPOGRAPHIC)
SW/4 DALLAS 15' QUADRANGLE
55'
280 000 FEET
DALLAS 4.6 MI.
84°52'30"
33°52'30"
Pace Creek
Baker Creek
Pumpkinvine Creek
1 400 000 FEET
1 MILE
7000 FEET
1 KILOMETRE

Figure 64

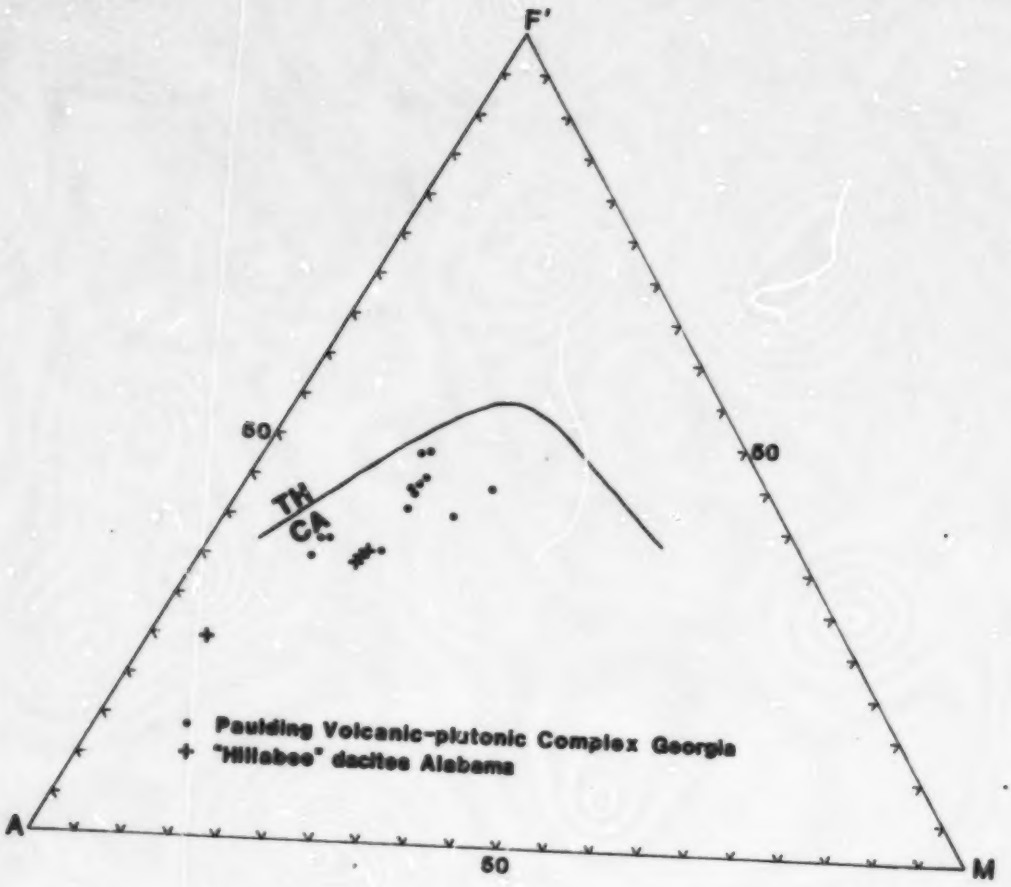

F'
50
50
TH
CA
A
50
M
• Paulding Volcanic-plutonic Complex Georgia
+ "Hillabee" dacites Alabama

FIGURE 65

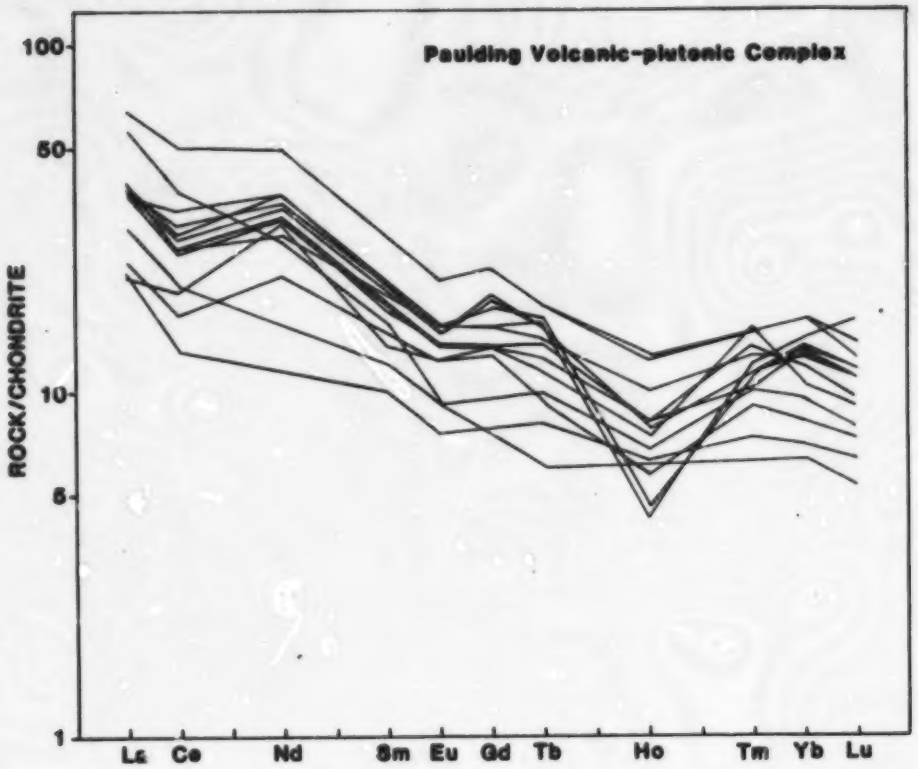

Paulding Volcanic-plutonic Complex
100
50
10
5
1
ROCK/CHONDRITE
La
Ce
Nd
Sm
Eu
Gd
Tb
Ho
Tm
Yb
Lu

FIGURE 66

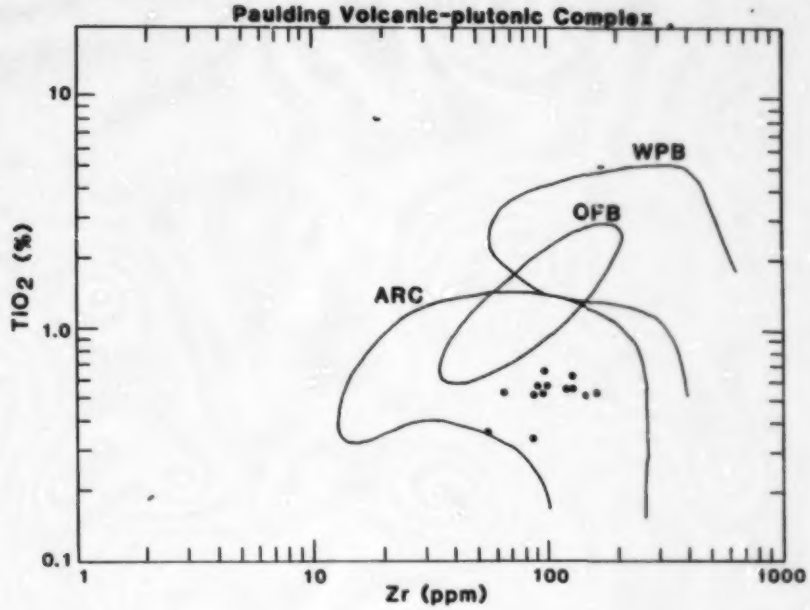
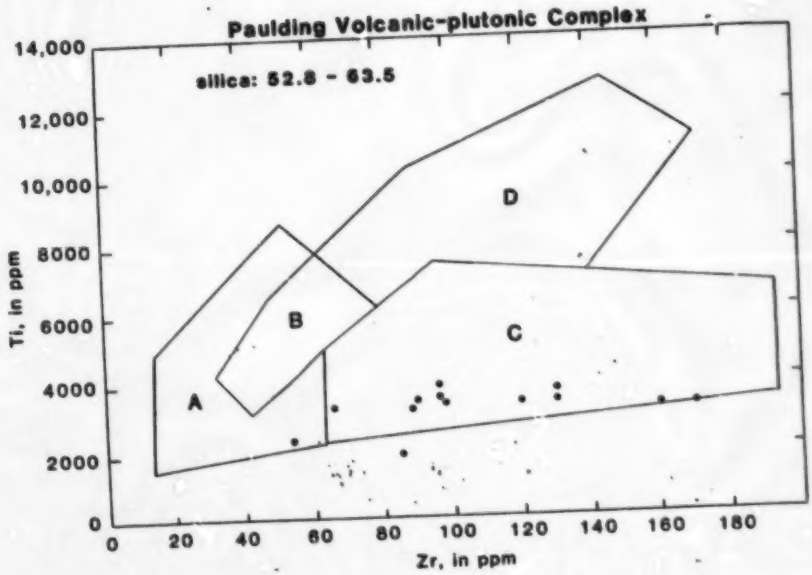


FIGURE 67B



FIELDS
A-B Low-potassium tholeiitic basalt of island arc series
B-C Calc-alkalic basalt of island arc series
B-D Ocean-floor basalt

FIGURE 67A

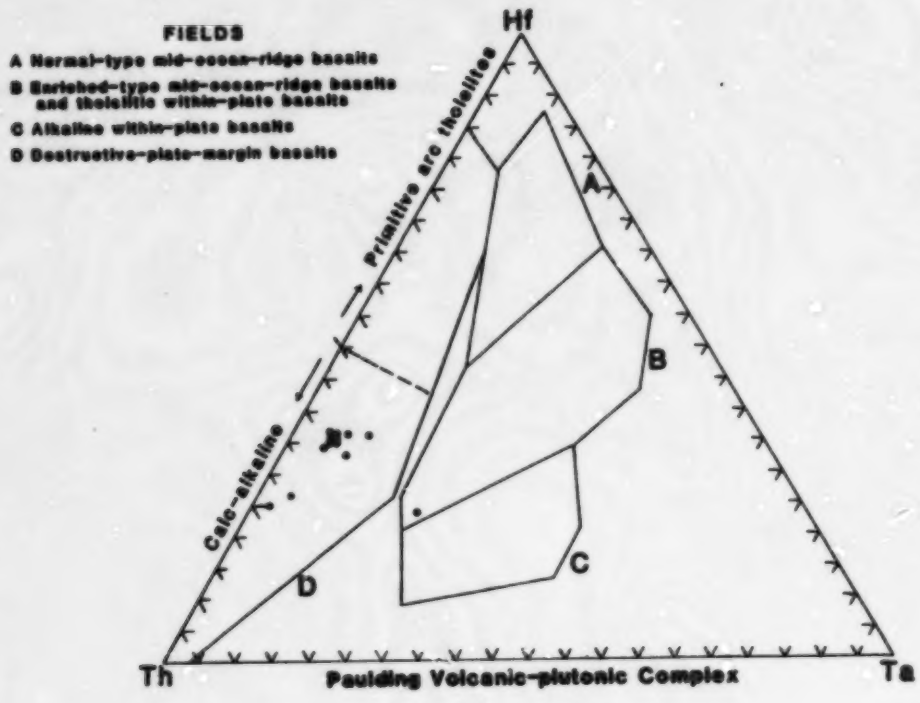
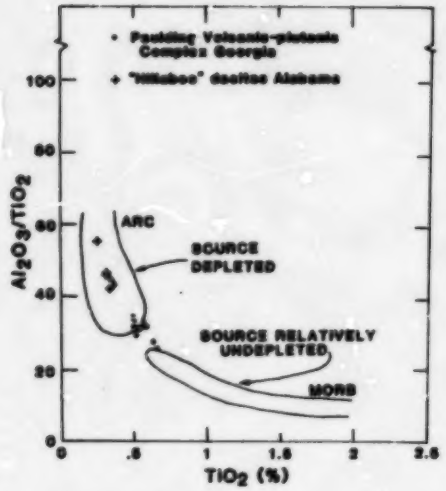

FIELDS
A Normal-type mid-ocean-ridge basalts
B Enriched-type mid-ocean-ridge basalts and tholeiitic within-plate basalts
C Alkaline within-plate basalts
D Destructive-plate-margin basalts
Hf
Primitive arc tholeiites
Calc-alkaline
A
B
C
D
Th
Paulding Volcanic-plutonic Complex
Ta

FIGURE 17C


Paulding Volcanic-plutonic Complex Georgia
"Hillabee" dacites Alabama
ARC
SOURCE DEPLETED
SOURCE RELATIVELY UNDEPLETED
MORB
Al_2O_3/TiO_2
TiO_2 (%)

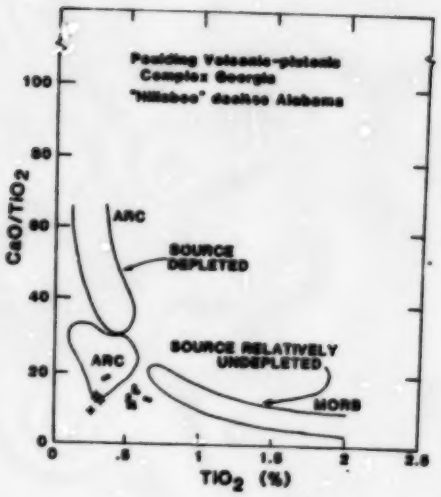

Paulding Volcanic-plutonic Complex Georgia
"Hillabee" dacites Alabama
ARC
SOURCE DEPLETED
ARC
SOURCE RELATIVELY UNDEPLETED
MORB
CaO/TiO_2
TiO_2 (%)

FIGURE 68

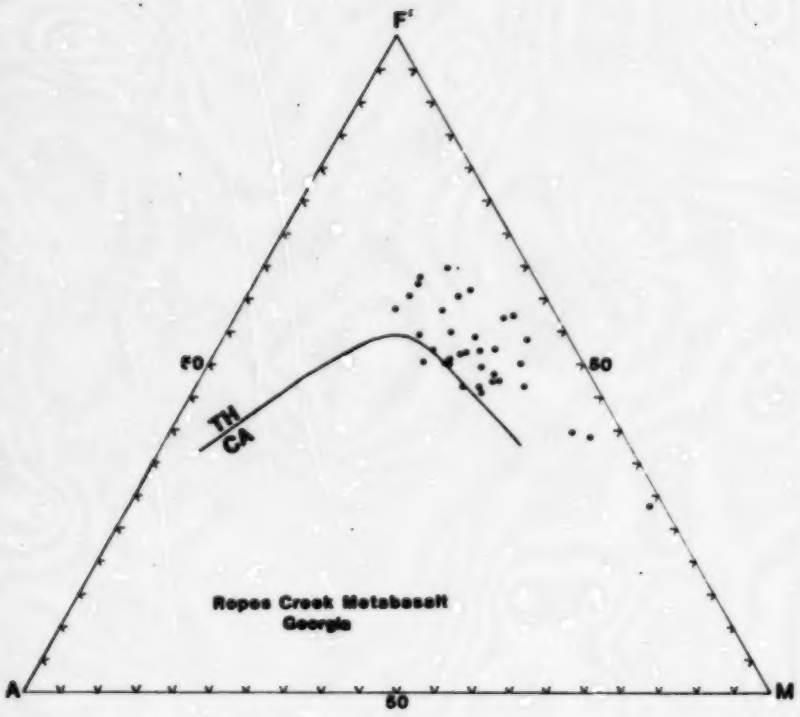


FIGURE 68

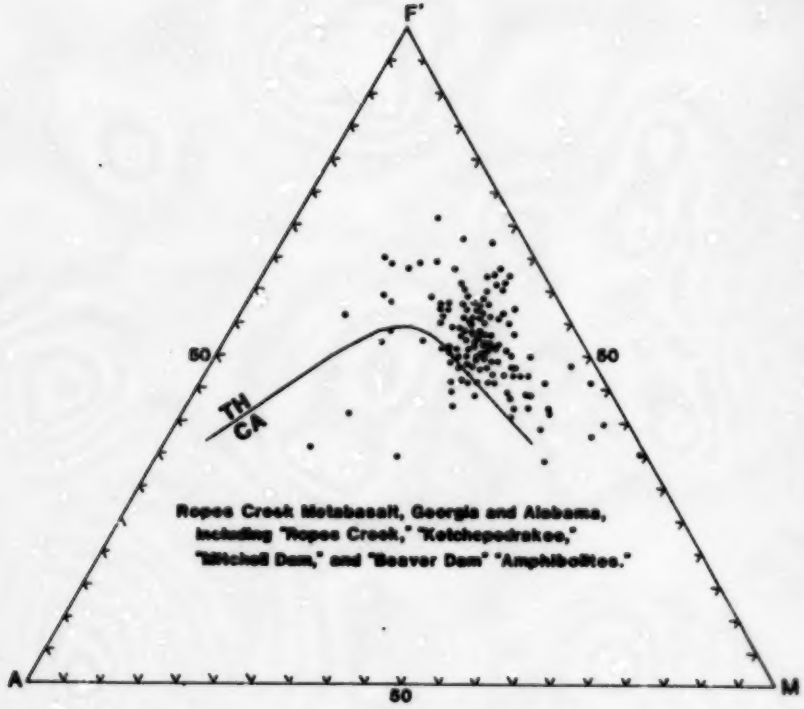
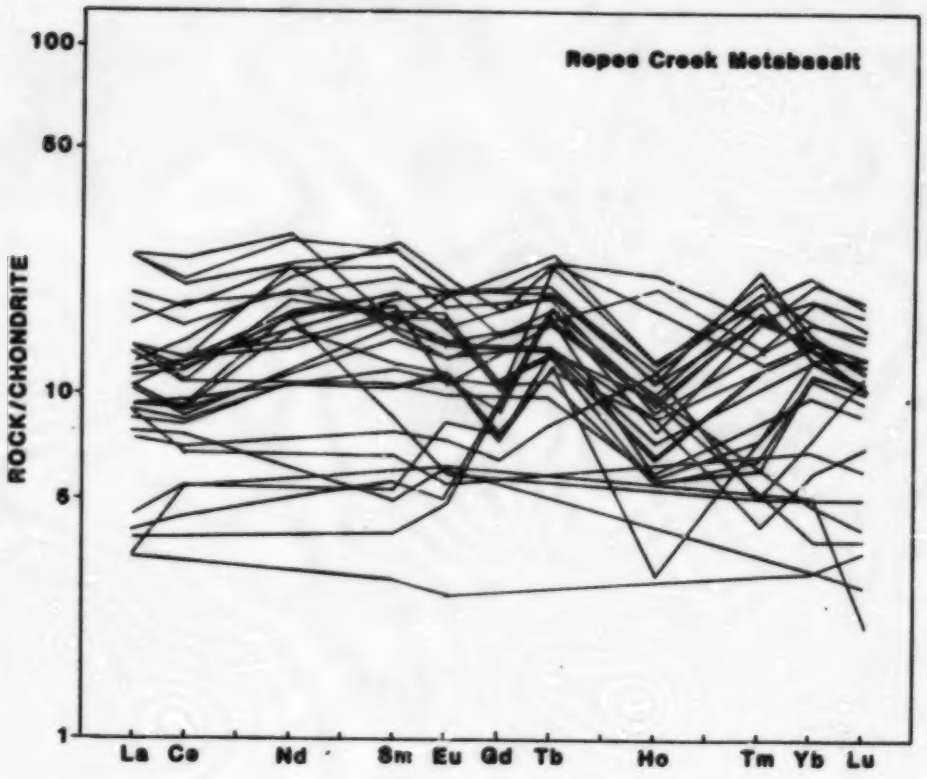
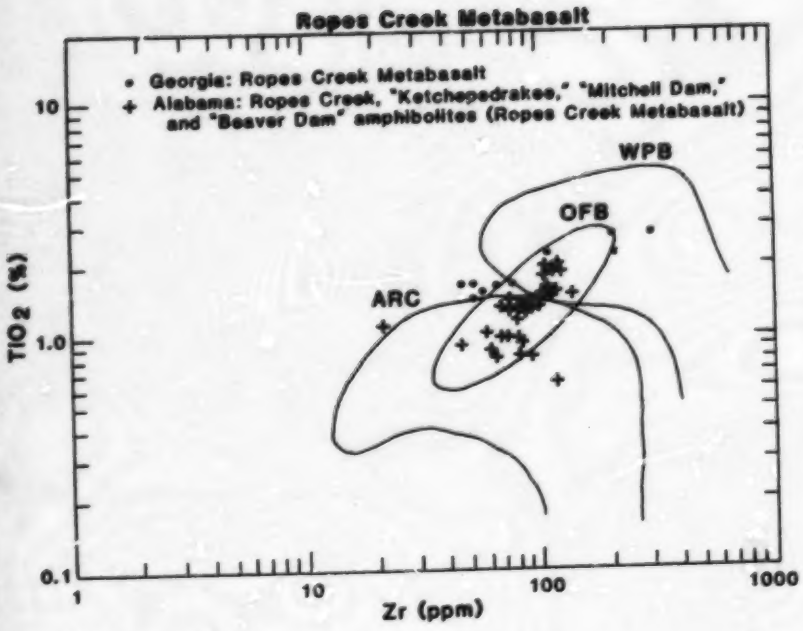


FIGURE 69


Ropes Creek Metabasalt
100
50
10
5
1
ROCK/CHONDRITE
La Ce Nd Sm Eu Gd Tb Ho Tm Yb Lu

FIQURE 70


Ropes Creek Metabasalt
• Georgia: Ropes Creek Metabasalt
+ Alabama: Ropes Creek, "Ketchepedrakes," "Mitchell Dam," and "Beaver Dam" amphibolites (Ropes Creek Metabasalt)
WPB
OFB
ARC
TiO2 (%)
10
1.0
0.1
1
10
100
1000
Zr (ppm)

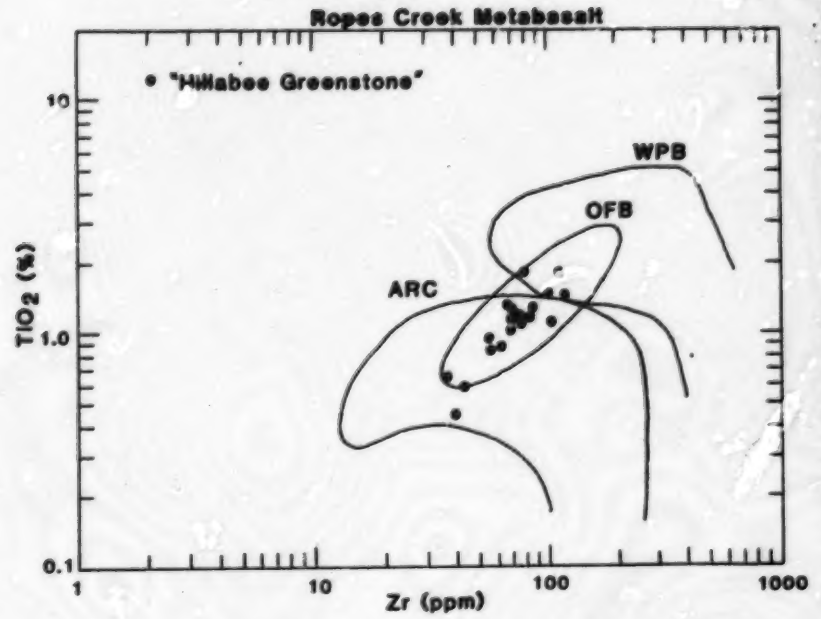
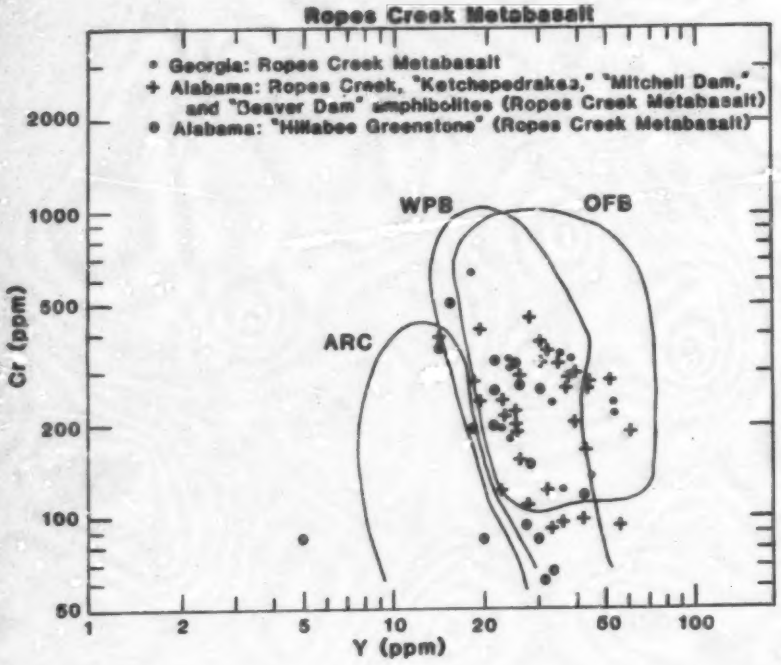

Ropes Creek Metabasalt
• "Hillabee Greenstone"
WPB
OFB
ARC
TiO2 (%)
10
1.0
0.1
1
10
100
1000
Zr (ppm)

FIGURE 71


Ropes Creek Metabasalt
• Georgia: Ropes Creek Metabasalt
+ Alabama: Ropes Creek, "Ketchepedrakes," "Mitchell Dam," and "Beaver Dam" amphibolites (Ropes Creek Metabasalt)
• Alabama: "Hillabee Greenstone" (Ropes Creek Metabasalt)
WPB
OFB
ARC
Cr (ppm)
Y (ppm)
2000
1000
500
200
100
50
1
2
5
10
20
50
100

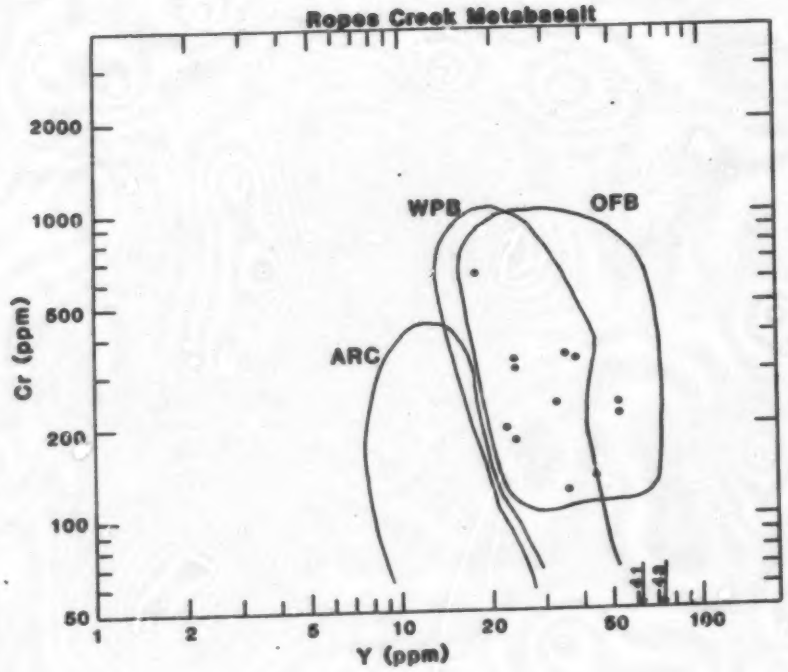
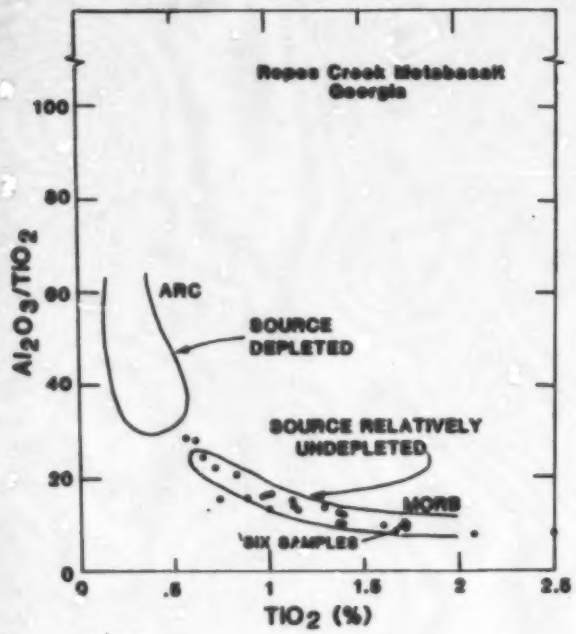

Ropes Creek Metabasalt
WPB
OFB
ARC
Cr (ppm)
Y (ppm)
2000
1000
500
200
100
50
1
2
5
10
20
50
100

FIGURE 72

06


Ropes Creek Metabasalt
Georgia
ARC
SOURCE
DEPLETED
SOURCE RELATIVELY
UNDEPLETED
MORB
SIX SAMPLES
Al_2O_3/TiO_2
TiO_2 (%)
0
20
40
60
80
100
.5
1
1.5
2
2.5

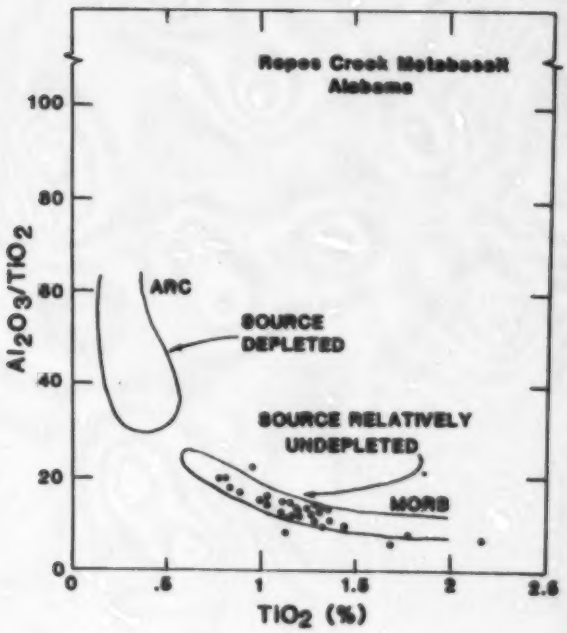
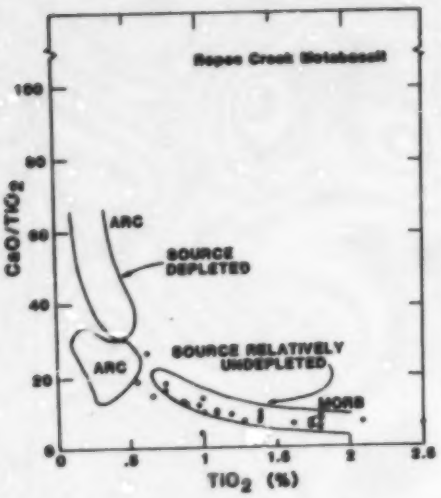

Ropes Creek Metabasalt
Alabama
ARC
SOURCE
DEPLETED
SOURCE RELATIVELY
UNDEPLETED
MORB
Al_2O_3/TiO_2
TiO_2 (%)
0
20
40
60
80
100
.5
1
1.5
2
2.5

FIGURE 73


Repose Creek Metabasalt
CaO/TiO2
100
80
60
40
20
0
ARC
SOURCE DEPLETED
ARC
SOURCE RELATIVELY UNDEPLETED
MORB
0
.5
1
1.5
2
2.5
TiO2 (%)

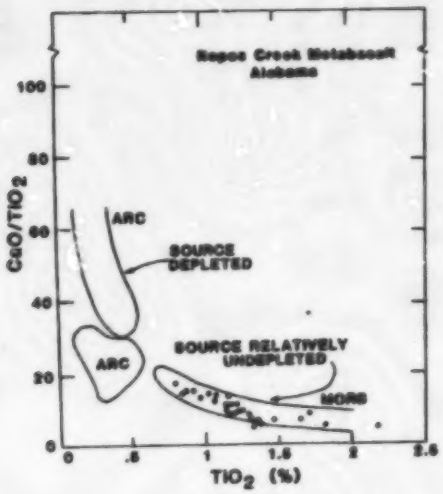

Repose Creek Metabasalt
Alabama
CaO/TiO2
100
80
60
40
20
0
ARC
SOURCE DEPLETED
ARC
SOURCE RELATIVELY UNDEPLETED
MORB
0
.5
1
1.5
2
2.5
TiO2 (%)

FIGURE 74

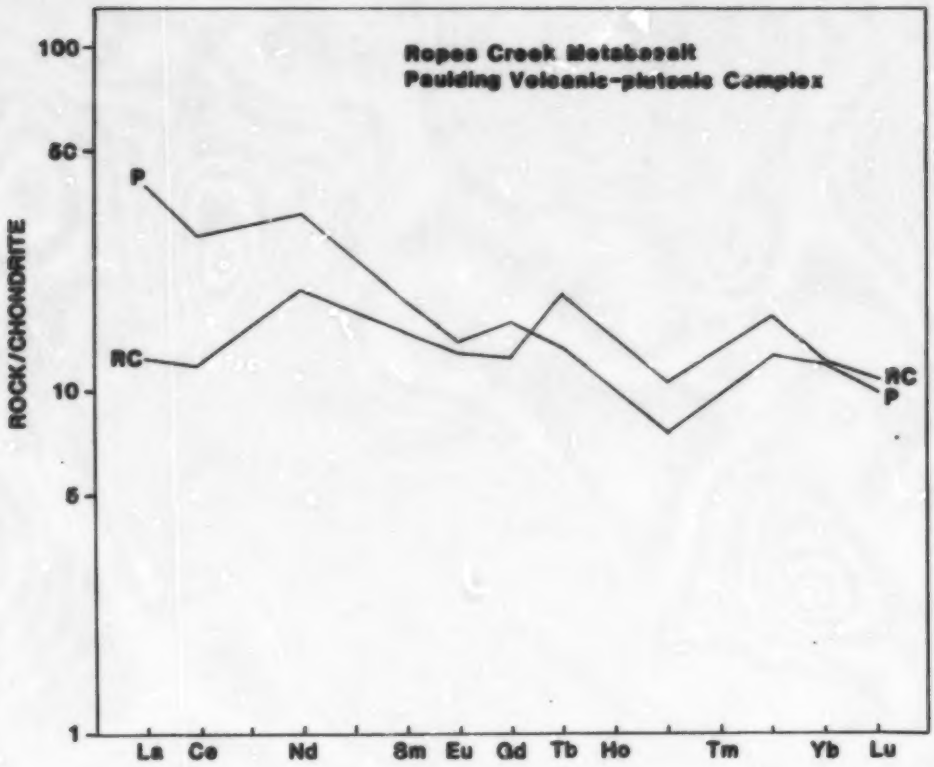

Ropes Creek Metabasalt
Paulding Volcanic-plutonic Complex
ROCK/CHONDRITE
100
50
10
5
1
P
RC
RC
P
La
Ce
Nd
Sm
Eu
Gd
Tb
Ho
Tm
Yb
Lu

FIGURE 75

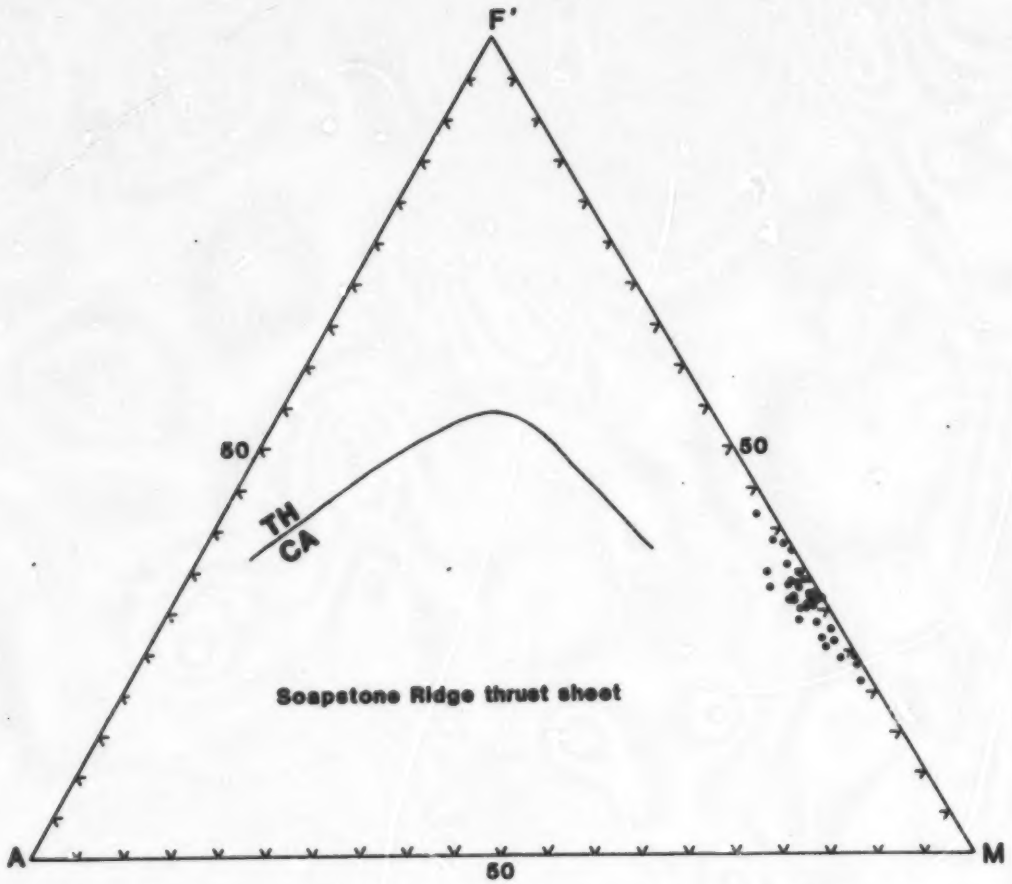


FIGURE 76

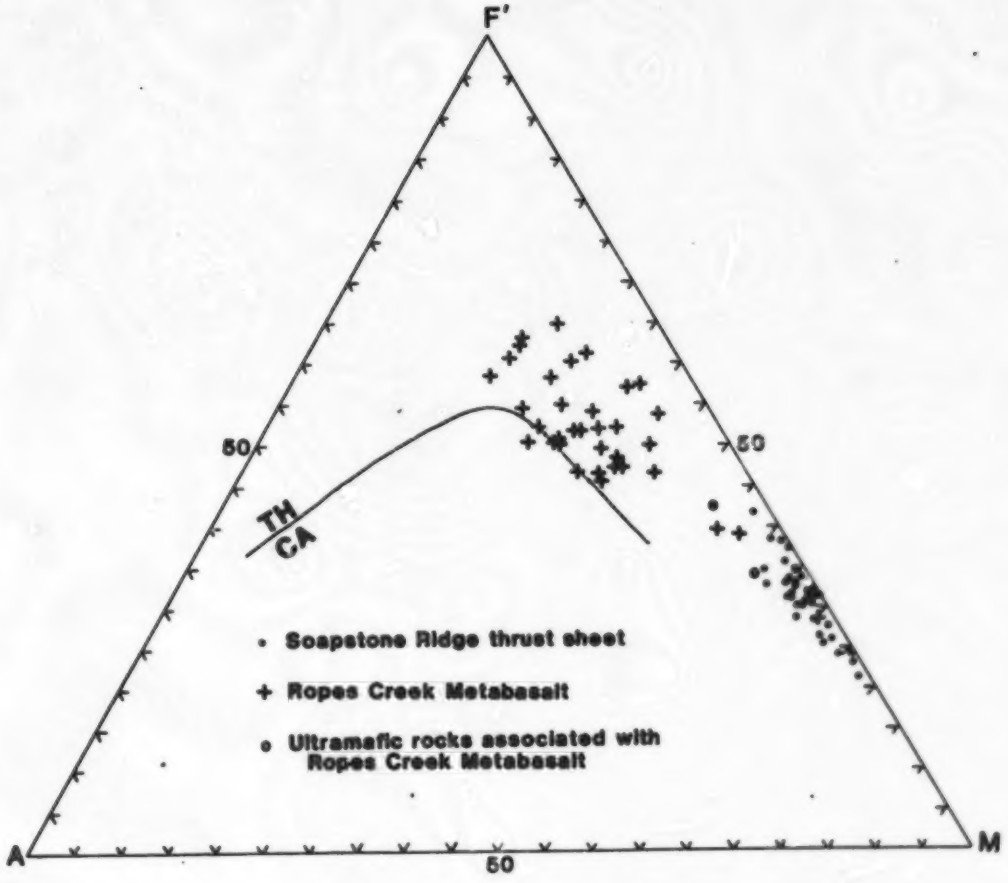

F'
50
50
TH
CA
• Soapstone Ridge thrust sheet
+ Ropes Creek Metabasalt
o Ultramafic rocks associated with Ropes Creek Metabasalt
A
M
50

FIGURE 77

DEPARTMENT OF INTERIOR

U.S. GEOLOGICAL SURVEY

OPEN-FILE REPORT 86-372

SHEET 1 of 2

EXPLANATION

- w — WAHOO CREEK THRUST SHEET
- c — CLAIRMONT THRUST SHEET
- z — ZEBULON THRUST SHEET
- m — MURPHY MARBLE
- e — ELLIJAY AND BLUE RIDGE GROUPS
- h — HOLLIS QUARTZITE
- b — BILL ARP THRUST SHEET
- t — TALLADEGA SLICE
- rc — ROCKMART SLATE AND TELLICO FORMATION
- rm — ROME THRUST SHEET
- cp — CLINCHPORT THRUST SHEET
- k — KINGSTON THRUST SHEET
- g — GRENVILLE BASEMENT
- l — LITTLE RIVER ALLOCHTHON
- mp — MACON MELANGE, Potato Creek slice
- mj — Juliette slice
- mb — Po Biddy slice
- mpb — Po Biddy and Potato Creek slices undivided
- o — ophiolite
- s — SOAPSTONE RIDGE THRUST SHEET (OPHIOLITE)
- r — ROPES CREEK THRUST SHEET (OPHIOLITE)
- rw — ROPES CREEK AND WEST POINT THRUST SHEETS UNDIVIDED
- rp — ROPES CREEK AND PAULDING THRUST SHEETS UNDIVIDED (WEST POINT THRUST SHEET)
- wp — WEST POINT THRUST SHEET
- p — PAULDING THRUST SHEET
- ss — SANDY SPRINGS THRUST SHEET
- pl — PROMISED LAND THRUST SHEET
- a — ATLANTA THRUST SHEET
- f — FROG MOUNTAIN SANDSTONE OR (AND) FORT PAYNE CHERT
- bsu — BILL ARP, ZEBULON, SANDY SPRINGS, ROPES CREEK, AND SOAPSTONE RIDGE THRUST SHEETS UNDIVIDED
- bzs — BILL ARP, ZEBULON, AND SANDY SPRINGS THRUST SHEETS UNDIVIDED
- gb — GEORGIABAMA THRUST STACK UNDIVIDED
- kp — K-FELDSPAR-POOR GRANITIC ROCKS
- gr — GRANITES AND GRANITE GNEISSES

CONTACT

THRUST FAULT, TEETH ON UPPER PLATE, DASHED WHERE APPROXIMATELY LOCATED

NORMAL FAULT, D-DOWNTHROWN SIDE, U-UPTHROWN SIDE

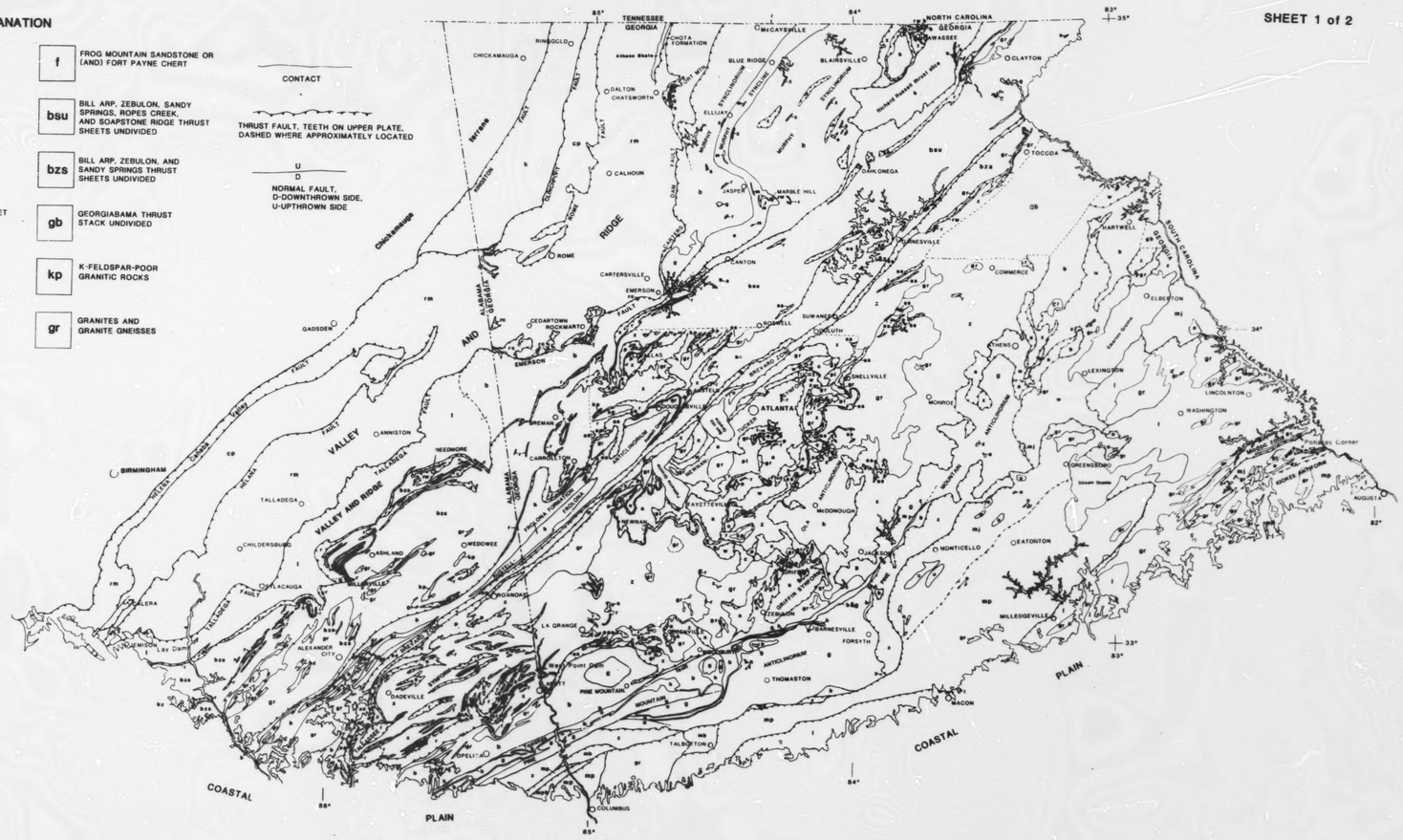
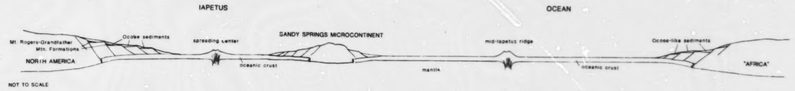


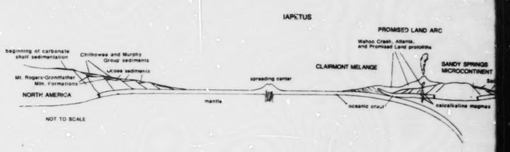
Figure 1. Generalized geologic-tectonic map of the southernmost part of the Appalachian orogen, Georgia and Alabama.

U.S. GEOLOGICAL SURVEY
DEPARTMENT OF THE INTERIOR

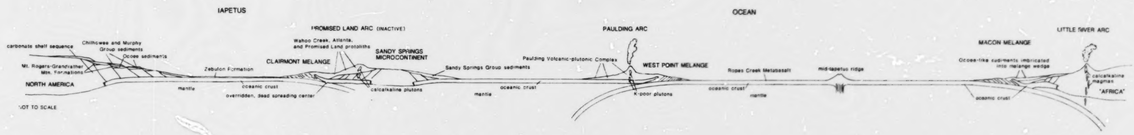
a. LATE PRECAMBRIAN - OCOEE TIME



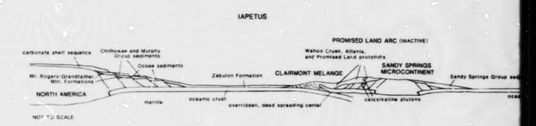
b. EARLY CAMBRIAN



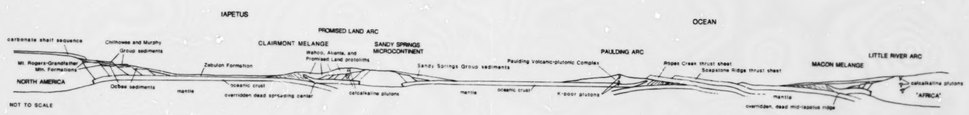
c. MIDDLE CAMBRIAN



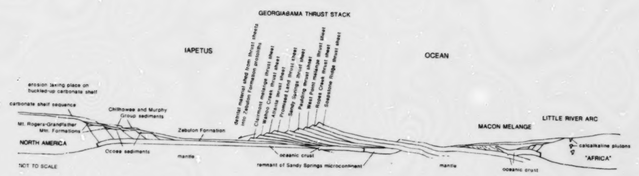
d. LATE CAMBRIAN



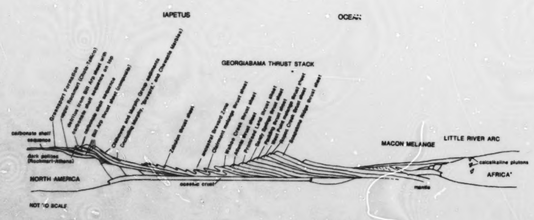
e. EARLY ORDOVICIAN



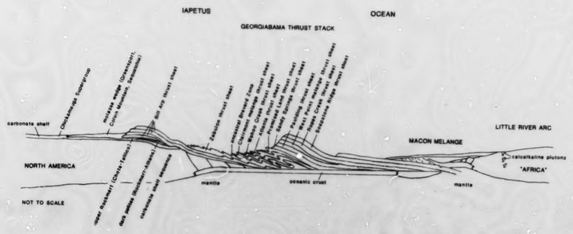
f. EARLY MIDDLE ORDOVICIAN



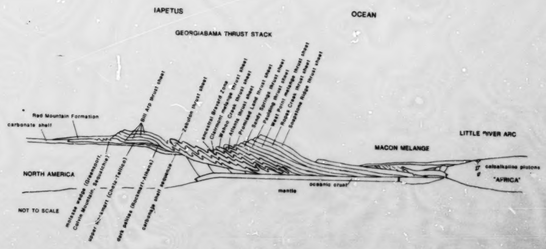
h. LATE MIDDLE ORDOVICIAN (UPPER ROCKMART-CHOTA-TELLICO TIME)



i. LATE ORDOVICIAN



j. SILURIAN



OCEAN

Ocean-like sediments

oceanic crust

"AFRICA"

b. EARLY CAMBRIAN

IAPETUS

beginning of carbonate shelf sedimentation

Chilhowee and Murphy Group sediments

Ocoee sediments

Mt. Rogers-Grandfather Mtn. Formations

NORTH AMERICA

NOT TO SCALE

spreading center

mantle

PROMISED LAND ARC

Wahoo Creek, Atlanta, and Promised Land protoliths

CLAIRMONT MELANGE

SANDY SPRINGS MICROCONTINENT

calcalkaline magmas

oceanic crust

Sandy Springs Group sediments

OCEAN

PAULDING ARC

Paulding Volcanic-plutonic Complex

K-poor magmas

WEST POINT MELANGE

Ropes Creek Metabasalt

mid-Iapetus ridge

MACON MELANGE

Ocean-like sediments imbricated into marginal wedge

LITTLE RIVER ARC

"AFRICA"

OCEAN

Ropes Creek Metabasalt

mid-Iapetus ridge

MACON MELANGE

Ocean-like sediments imbricated into marginal wedge

LITTLE RIVER ARC

calcalkaline magmas

"AFRICA"

oceanic crust

mantle

d. LATE CAMBRIAN

IAPETUS

carbonate shelf sequence

Chilhowee and Murphy Group sediments

Ocoee sediments

Mt. Rogers-Grandfather Mtn. Formations

NORTH AMERICA

NOT TO SCALE

Zebulon Formation

overridden, dead spreading center

PROMISED LAND ARC (INACTIVE)

Wahoo Creek, Atlanta, and Promised Land protoliths

CLAIRMONT MELANGE

SANDY SPRINGS MICROCONTINENT

calcalkaline plutons

Sandy Springs Group sediments

OCEAN

PAULDING ARC

Paulding Volcanic-plutonic Complex

K-poor plutons

WEST POINT MELANGE

Soapstone Ridge thrust sheet

Ropes Creek Metabasalt

MACON MELANGE

overridden, dead mid-Iapetus ridge

LITTLE RIVER ARC (INACTIVE)

calcalkaline plutons

"AFRICA"

LITTLE RIVER ARC

calcalkaline plutons

"AFRICA"

f. EARLY MIDDLE ORDOVICIAN

IAPETUS

erosion taking place on tilted-up carbonate shelf

carbonate shelf sequence

Chilhowee and Murphy Group sediments

Ocoee sediments

Mt. Rogers-Grandfather Mtn. Formations

NORTH AMERICA

NOT TO SCALE

Zebulon Formation

mantle

GEORGIABAMA THRUST STACK

Bethlehem Church thrust sheet

Talbotton thrust sheet

Fall Line thrust sheet

Pinetucky thrust sheet

Whitesburg thrust sheet

Ellijay thrust sheet

Talking Rock thrust sheet

Sandy Springs thrust sheet

Paulding thrust sheet

Ropes Creek thrust sheet

Soapstone Ridge thrust sheet

oceanic crust

remnant of Sandy Springs microcontinent

OCEAN

MACON MELANGE

mantle

oceanic crust

LITTLE RIVER ARC

calcalkaline plutons

"AFRICA"

g. MIDDLE MIDDLE ORDOVICIAN (ROCKMART-ATHENS TIME)

IAPETUS

carbonate shelf sequence

Mt. Rogers-Grandfather Mtn. Formations

NORTH AMERICA

NOT TO SCALE

mantle

Rich Mountain thrust sheet

Sandstone Shelf thrust sheet

Big Ridge thrust sheet

Chilhowee and Murphy Group sediments (Ocoee?)

Zebulon thrust sheet

GEORGIABAMA THRUST STACK

Bethlehem Church thrust sheet

Talbotton thrust sheet

Fall Line thrust sheet

Pinetucky thrust sheet

Whitesburg thrust sheet

Ellijay thrust sheet

Talking Rock thrust sheet

Sandy Springs thrust sheet

Paulding thrust sheet

Ropes Creek thrust sheet

Soapstone Ridge thrust sheet

oceanic crust

OCEAN

MACON MELANGE

mantle

LITTLE RIVER ARC

calcalkaline plutons

"AFRICA"

IAPETUS

GEORGIABAMA THRUST STACK

OCEAN

MACON MELANGE

LITTLE RIVER ARC

calcalkaline plutons

"AFRICA"

oceanic crust

mantle

i. SILURIAN

IAPETUS

GEORGIABAMA THRUST STACK

OCEAN

Red Mountain Formation

carbonate shelf

NORTH AMERICA

NOT TO SCALE

Bethlehem Church thrust sheet

Talbotton thrust sheet

Fall Line thrust sheet

Pinetucky thrust sheet

Whitesburg thrust sheet

Ellijay thrust sheet

Talking Rock thrust sheet

Sandy Springs thrust sheet

Paulding thrust sheet

Ropes Creek thrust sheet

Soapstone Ridge thrust sheet

MACON MELANGE

LITTLE RIVER ARC

calcalkaline plutons

"AFRICA"

oceanic crust

mantle

k. MIDDLE DEVONIAN

IAPETUS

GEORGIABAMA THRUST STACK

OCEAN

Red Mountain Formation

carbonate shelf

NORTH AMERICA

NOT TO SCALE

Bethlehem Church thrust sheet

Talbotton thrust sheet

Fall Line thrust sheet

Pinetucky thrust sheet

Whitesburg thrust sheet

Ellijay thrust sheet

Talking Rock thrust sheet

Sandy Springs thrust sheet

Paulding thrust sheet

Ropes Creek thrust sheet

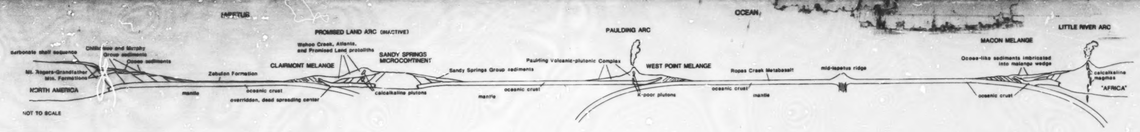
Soapstone Ridge thrust sheet

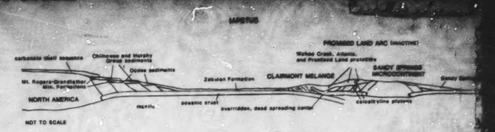
LITTLE RIVER THRUST STACK

Little River stockmass

Macon melange thrust sheet

"AFRICA"





e. EARLY ORDOVICIAN

f. EARLY MIDDLE ORDOVICIAN

h. LATE MIDDLE ORDOVICIAN (UPPER ROCKMART-CHOTA-TELLICO TIME)

i. LATE ORDOVICIAN

j. SILURIAN

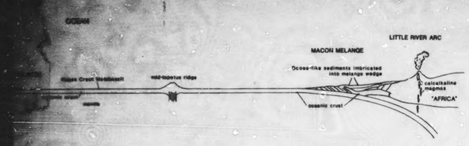
k. LATE DEVONIAN

m. EARLY CARBONIFEROUS

n. LATE CARBONIFEROUS

o. PRESENT

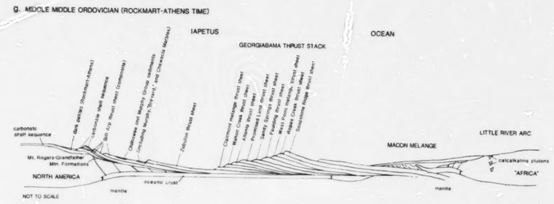
FIGURE 61–SCHEMATIC DIAGRAMS ILLUSTRATING EVOLUTION OF THE SOUTHERNMOST APPALACHIANS

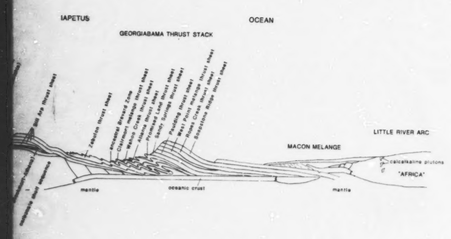


d. LATE CAMBRIAN

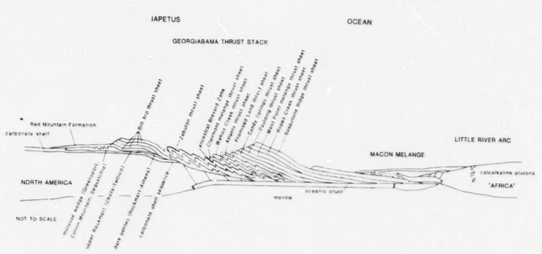
f. EARLY MIDDLE ORDOVICIAN

g. MIDDLE MIDDLE ORDOVICIAN (ROCKMART-ATHENS TIME)

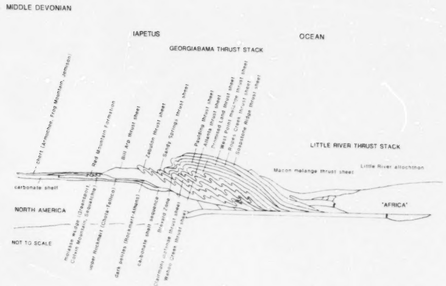


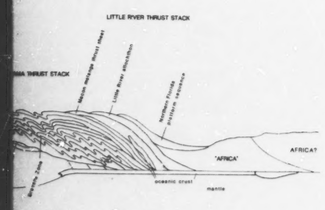


j. SILURIAN

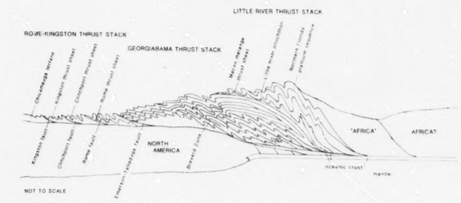


k. MIDDLE DEVONIAN





n. LATE CARBONIFEROUS



O. PRESENT

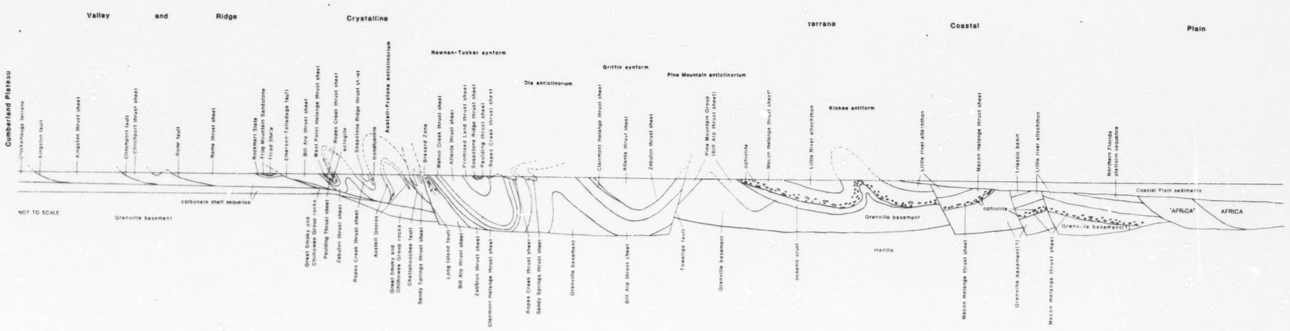


FIGURE 61-SCHEMATIC DIAGRAMS ILLUSTRATING EVOLUTION OF THE SOUTHERNMOST APPALACHIANS